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Electronic Manufacturing Process Improvement (EMPI) For Printed Wiring Assemblies

Program Task 3: Experimental Results Volume II: Appendices

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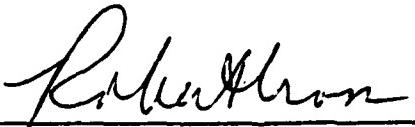
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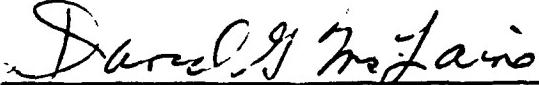
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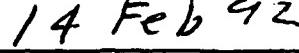
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13. ABSTRACT

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The baseline costs where developed using Cps and Cpks developed in the "intra" studies. These will than be compared to the costs developed from the Cps and Cpks generated based on the "inter" studies.

Also included in this report are yield and cycle time goals that have been developed by calculating what a 100% first pass yield produced as the potential overall cost saving possible and measuring that against the "intra" baseline to derive the "inter" goals.

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INTRODUCTION

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Also included in this report are yield and cycle time goals that have been developed by calculating what a 100% first pass yield produced as the potential overall cost saving possible and measuring that against the "intra" baseline to derive the "inter" goals.

There are significant cost saving that cannot be quantified in this cost model that are directly related to yield improvements and there are other savings that will result from just improving the control of the process. The items listed below represent the most significant:

1. Production test yields will be increased by sending better quality PWA's, with less handling, to the testers. Less workmanship defects will escape to test and reduced handling will reduce human induced defects.

2. The product produced by a controlled process environment will be more reliable and reduce "life cycle costs" by increasing MTBFs. This will reduce repair costs and lower the cost of spares (by reducing the amount required) for logistic support.

3. Inventories costs will be reduced by yield improvements and cycle time reduction. Shorter cycle times translate into increased inventory turns and lower inventory holding costs. Improved yields translate into less inventory required to replace scraped parts.

4. The use of EMPI methodology on other production processes will provide cost savings similar to the PWA process. The experience and knowledge from EMPI can provide a payoff on other processes.

5. Finally all of the above cost reductions will require less Manufacturing overhead support further reducing the cost of the product.

Capability

Yield is an important issue for any process. Often we compute the yield empirically as the number of good pieces divided by the number of pieces in the lot. This intuitive indicator is often satisfactory, but it has a substantial drawback. Unless the size of the production lots are very large, the number of good pieces changes considerably from lot to lot.

A more robust indicator of the process's yield is the Capability Index. The C_p is simply (Figure 1) the spec range (USL-LSL) divided by the process range (upl-lpl). A C_p of 1 indicates that the spec range and the process range are the same, and yield will closely approach 100%. Smaller C_ps indicate that the spec range is narrower than the process range (as in Figure 1), and the yield will be smaller. The smaller the C_p, the worse the situation. C_ps larger than 1 indicate a margin for error. The larger the C_p, the more secure the process. Typically, C_ps of at least 1.33 are recommended. Japanese processes average a C_p of 5.
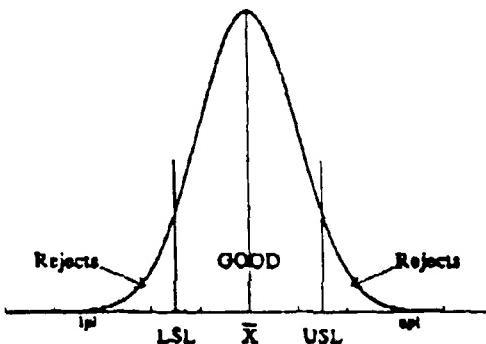
Figure 1. Process Capability (C_p)

To compute C_p, one must know the spec range and the process range. The spec range is always given. The process range must be computed. To compute the process range, take relevant measurements from all the pieces in an entire lot. Find their mean and their standard deviation.

$$Standard\ Deviation = \sigma = \sqrt{\frac{\sum (x - \bar{X})^2}{n-1}}$$

If the data is normally distributed (typically a reasonable approximation), then six times the standard deviation (the "6σ range") will encompass 99.73% of all the process data. This 6σ range is thus taken to be the process range.

This index is fine for centered processes. Modern treatments recognize, however, that processes are rarely centered within the spec range (Figure 2). To compensate for this reality, we typically compute two half-range capability indices. Each half-range index is called C_{pk}.

$$C_{Pk} = \frac{\overline{X} - LSL}{3\sigma} \quad or \quad \frac{USL - \overline{X}}{3\sigma}$$

where 3σ is 3 standard deviations or one-half of 6σ. ·
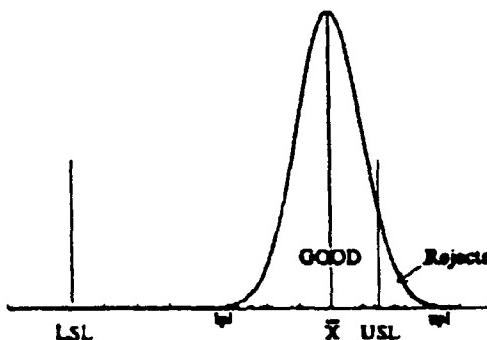
Figure 2. Half-Range Process Capability (C_{Pk})

There is a simple relationship between a C_{Pk} and its related yield. Considering the equations above, if the C_{Pk} is 1, that means that the related spec limit is 3σ away from the process mean. If the C_{Pk} is 2, then the spec limit is 6σ away from the mean. Thus the distance of the spec limit from the mean, in σs, is just 3 times the C_{Pk}. We find the yield by first finding the total defect rate. Assuming a normal distribution of the data, to find the defect rate, one simply has to look up the area beyond the corresponding number of σs. Both C_{Pk}s should be computed, and their corresponding defect rates found. The sum of the defect rates for each C_{Pk} is the total defect rate for the process. Yield, of course, is 1 - total defect rate.

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Using Experimental Data to Compute Capability

Production run data is best for the computation of the 6σ range, but if that is not available, short run experimental data can be used in its place.

In a typical industrial experiment, each process factor is pushed to its widest natural range. This pushes the process output to the edge of the 6σ range due to this factor. If all factors are known, then the 6σ range of the process is simply the statistical sum of the variabilities due to each factor. As computed in an analysis of variance table, this is the sum of the mean-squares for each factor.

If all process factors are not known, then the analysis of variance error term must be included. This error term does not represent its 6σ range, however. The error term has not been pushed to its limits. Instead, the mean-square for error in an analysis of variance table corresponds to a 1σ range. It must be multiplied by 36 (i.e., 6^2) to correspond to the 6σ range.

$$36\sigma^2_{Total} = \sum (36\sigma^2_{Factors}) + 36\sigma^2_{Error}$$

One more correction must be included, however. Each computed Mean Square in an Analysis of Variance table actually includes both the variability due to the factor and the variability due to error, i.e., in this case, $MS_{Factor} = 36\sigma^2_{Factor} + \sigma^2_{Error}$. Therefore, if there are k factors, then the total variability is given by

$$36\sigma^2_{Total} = \sum MS_{Factors} - (36-k)\sigma^2_{Error}$$

The total 6σ range, of course, is simply the square root of the computed $36\sigma^2_{Total}$.

On the following pages, I show the specific computations for each factor. To eliminate the likelihood of computational error, I have couched the computations in Analysis of Variance format. To translate to VIPS format,

$$MS_{Factor} = \frac{n}{2}\sum (VIPS)^2$$

where n is the number of observations in each level of each factor.

INDIVIDUAL DATA ASSUMPTIONS AND COMPUTATIONS

STANDOFF

ADHESIVE DOT (Raw data)

From this data, $\overline{X} = 6.48$ and $6\sigma = 6.12$

$$C_P = \frac{2}{6.12} = 0.33 \qquad \dot{C}_{Pk} = \frac{-.48}{3.06} = -.15$$

Yield = .32

PASTE DEPOSITION

PASTE SLUMP (Perpendicular to blade, FPD)

Factor	MS
A	0.125
C	0.125
D	0.000
E	1.125
F	0.500
Error	0.063

$$\overline{X}_0 = 0.625 \qquad 6\sigma = \sqrt{1.875 + 31 \times 0.0625} = 1.95$$

$$C_P = \frac{3}{1.95} = 1.54 \qquad C_{Pk} = \frac{2.375}{0.98} = 2.42$$

Yield = 1.00

PASTE REGISTRATION (Base registration offset, worst case)

Factor	MS
A	26.523
Error	0.023

$$\overline{X} = 1.575 \qquad 6\sigma = \sqrt{26.52 + 35 \times 0.023} = 5.226$$

$$C_P = \frac{7}{5.23} = 1.34 \qquad C_{Pk} = \frac{1.925}{2.61} = 0.74$$

Yield = .99

SOLDER PASTE (CONTINUED)

SPIKES (Height above deposit, perpendicular to blade, FPD)

Factor	MS
A	15.40
C	0.66
D	0.10
E	7.03
F	1.20
Error	2.54

$$\overline{X_0} = 3.625 \qquad 6\sigma = \sqrt{24.396 + 31 \times 2.536} = 10.15$$

$$C_p = \frac{6}{10.14} = 0.59 \qquad C_{Pk} = \frac{2.375}{5.07} = 0.47$$

Yield = .92

THICKNESS (Perpendicular to blade, FPD)

Factor	MS
A	13.01
C	2.42
D	2.00
E	0.13
F	2.21
Error	0.46

$$\overline{X_0} = 7.225 \qquad 6\sigma = \sqrt{19.755 + 31 \times 0.4625} = 5.84$$

$$C_p = \frac{3}{5.84} = 0.51 \qquad C_{Pk} = \frac{.275}{2.92} = 0.09$$

Yield = .61

But since stencil thickness would have been modified to optimal thickness, $C_{Pk} = C_p = .51$ and

Yield = .88

SOLDER PASTE (CONTINUED)

SMEAR (Blob beyond deposit edge, FPD)

Factor	MS
A	4.50
C	2.00
D	2.00
E	24.50
F	4.50
Error	3.25

$$\overline{X}_c = 1.25 \qquad 6\sigma = \sqrt{37.5 + 31 \times 3.25} = 11.76$$

$$C_p = \frac{3}{11.76} = 0.26 \qquad C_{pk} = \frac{1.75}{5.88} = 0.30$$

Yield = .81

Total Yield = 1.00 x .99 x .92 x .88 x .81 = .65

COMPONENT FORMING

LEAD FOOT ANGLE

No Measurable Variability

$$\overline{X} = 3 \qquad 6\sigma = \sqrt{0} = 0$$

$$C_p = \frac{30}{0} = \infty \qquad C_{pk} = \frac{12}{0} = \infty$$

Yield = 1.00

COMPONENT FORMING (CONTINUED)

BELLY TO TOE

Factor	MS
A	0.0625
B	0.0625
Error	0.0625

$$\overline{X} = 16.1 \qquad 6\sigma = \sqrt{.125 + 34 \times 0.0625} = 1.5$$

$$C_P = \frac{4}{1.5} = 2.67 \qquad C_{pk} = \frac{.90}{.75} = 1.2$$

Yield = 1.00

COPLANARITY (Use worst case data.)

Factor	MS
A	0
B	0
Error	0

$$\overline{X} = 1 \qquad 6\sigma = \sqrt{0} = 0$$

$$C_P = \frac{4}{0} = \infty \qquad C_{pk} = \frac{1}{0} = \infty$$

Yield = 1.00

COMPONENT FORMING (CONTINUED)

LEAD SKEW (Use worst case)

Factor	MS
A	0.250
B	0.000
Error	0.000

$$\tilde{X} = 1.25 \qquad 6\sigma = \sqrt{.25 + 34 \times 0.00} = 0.50$$

$$C_p = \frac{2.50}{0.50} = 5.00 \qquad C_{Pk} = \frac{1.25}{0.25} = 5.00$$

Yield = 1.00

TOE TO TOE (Use worst case)

Factor	MS
A	0.25
B	0.25
Error	0.25

$$\overline{X} = 1215.75 \qquad 6\sigma = \sqrt{0.50 + 34 \times 0.25} = 3.00$$

$$C_p = \frac{10}{3.00} = 3.33 \qquad C_{Pk} = \frac{0.75}{1.50} = 0.50$$

Yield = .93

COMPONENT FORMING (CONTINUED)

LEAD TOE BURR (Use worst case)

Factor	MS
A	0.002
B	0.563
Error	0.122

$$\bar{X} = 3.025 \qquad 6\sigma = \sqrt{.565 + 34 \times 0.122} = 2.17$$

$$C_p = \frac{5}{2.17} = 2.30 \qquad C_{PK} = \frac{1.975}{1.09} = 1.81$$

Yield = 1.00

Total Yield = 1.00 x 1.00 x 1.00 x 1.00 x .93 x 1.00 = .93

COMPONENT TINNING

LEAD SOLDER COVERAGE (MIN) (Use worst case)

Factor	MS
A	312.5
B	0.0
C	312.5
D	1250.0
E	312.5
F	1250.0
Error	312.5

$$\bar{X} = 50.0 \qquad 6\sigma = \sqrt{3437.5 + 30 \times 312.5} = 113.2$$

$$C_{PK} = \frac{25.0}{56.6} = 0.44$$

Yield = .91

As a practical matter, the depth of tinning would be increased until a yield of 1.00 was obtained.

COMPONENT TINNING (CONTINUED)

LEAD SOLDER VOLUME

Factor	MS
A	0.018
B	0.006
C	0.009
D	0.002
E	0.009
F	0.107
Error	0.002

$$\overline{X} = .2656 \qquad 6\sigma = \sqrt{.1516 + 30 \times 0.001922} = .457$$

$$C_P = \frac{3}{.457} = 6.56 \qquad C_{Pk} = \frac{2.7}{.229} = 11.80$$

Yield = 1.00

Total Yield = 1.00 x 1.00 = 1.00

COMPONENT PLACEMENT

LEAD PENETRATION (Use worst case)

Factor	MS
A	0.063
B	0.203
C	0.063

$$\overline{X} = -0.88 \qquad 6\sigma = \sqrt{.329} = .574$$

$$C_P = \frac{3}{.574} = 5.23 \qquad C_{Pk} = \frac{-0.88}{.287} = 3.07$$

Yield = 2 X 10^{-38}

As a practical matter, force would be increased until yield was 1.00.

COMPONENT PLACEMENT (CONTINUED)

LEAD/PAD ALIGNMENT (Used greatest Δ of 4 points)

Factor	MS
A	0.25
B	0.25
C	0.00

$$\bar{X} = 0.50 \qquad 6\sigma = \sqrt{.25+.25+0} = .71$$

$$C_P = \frac{4}{.71} = 5.63 \qquad C_{Pk} = \frac{1.5}{.354} = 4.24$$

Yield = 1.00

Total Yield = 1.00 x 1.00 = 1.00

REFLOW

SOLDER JOINT TEMPERATURE (Used worst case thermocouple)

Factor	MS
A	119.90
B	125.44
C	8.12
D'	1.69
E	74.82
F	5.29
Error	2.55

$$\bar{X} = 233.15 \qquad 6\sigma = \sqrt{335.26+30\times2.55} = 20.29$$

$$C_P = \frac{11}{20.29} = .54 \qquad C_{Pk} = \frac{5.5}{10.15} = .54$$

Yield = .90

This would be corrected immediately without loss of boards, so actual yield = 1.00.

REFLOW (CONTINUED)

SURFACE FINISH (Used your data)

Factor	MS
A	0.25
B	1.00
C	1.00
D	1.00
E	0.00
F	0.25
Error	0.47

$$\bar{x} = 2.125 \qquad 6\sigma = \sqrt{3.5 + 30 \times 0.472} = 4.20$$

$$C_p = \frac{2}{4.20} = 0.48 \qquad\qquad C_{p\lambda} = \frac{.875}{2.10} = 0.42$$

Defect rate = .106

$$C_{p\gamma} = \frac{1.125}{2.10} = 0.54$$

Defect rate = .054
Total Defect rate = .16

Yield = .84

CLEANLINESS

VISUAL INSPECTION (Used your data)

Factor	MS
A	0.563
B	0.063
C	1.563
D	0.563
E	1.563
F	7.563
G	0.063
Error	2.938

$$\bar{X} = 2.3125 \qquad 6\sigma = \sqrt{11.9375 + 29 \times 2.9375} = 9.86$$

$$C_p = \frac{1}{9.86} = 0.10 \qquad C_{pk} = \frac{-1.31}{4.93} = -0.27$$

$$\text{Yield} = .21$$

"INTER" STUDY

YIELD IMPROVEMENT GOALS

&

COST SAVING POTENTIAL

"INTER" STUDY YIELD GOALS

WORKCELLS	"INTRA" BASELINE FIRST PASS YIELD (%)	"INTER" GOAL FIRST PASS YIELD (%)
DRY FILM STANDOFF APPLICATION	32	98
SOLDER PASTE	65	85
LEADED COMPONENT FORMING	93	95
LEADED COMPONENT TINNING	100	98
COMPONENT PLACEMENT	100	90
REFLOW (VISUAL)	84	90
CLEANING	21	95
TOTAL	3	60

OBSERVED 17%

OBSERVED 85%

IMPROVE OVERALL 1ST PASS YIELD TO 70%

A-19

BASELINE
SUMMARY COST MODEL
(100 BD LOT)

INTRA YIELD	PROCESS	ADD COMP	COST 1ST PASS YIELD	COST "INTRA" YIELD	POTENTIAL IMPROVE	POTENTIAL COST SAV
32%	STAND OFF	PWB	$757	$2387	68%	$167
65	STENCIL PRT		272	439	40	167
93	FORMING	FPD	1176	1264	7	88
100	TINNING		591	591		
100	PLACEMENT	RCC/ RLC	852	852		
84	REFLOW		2080	2978	43	898
21	CLEAN		455	1482	69	1027
			6183	9993	38	3810

POTENTIAL COST IMPROVEMENT

MATERIAL	$13840
PROCESS	3810

$17650

A-20

BASELINE
MATERIAL (1% SCRAP)

PROCESS	COST	POTENTIAL IMPROVE
STANDOFF PWB	$100,000	0
FORMING FPD	450,000	$4500
PLACEMENT	192,000	1920

$6420	→ COMPONENT LOSS
$7420	→ PWA LOSS
$13840	→ POTENTIAL MAT. IMPROVEMENT

100 BD LOT

MATERIAL COST/BD

PWB - $1000 @ 1 1000

FPD - $500 @ 9 4500

LCC/RTC - @85 1920

$7420
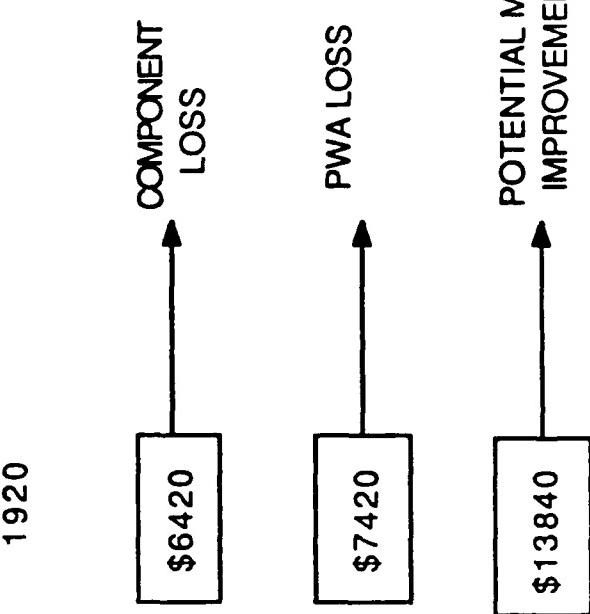
1% SCRAP AT FINAL ASSEMBLE

BASELINE
COMPONENT STANDOFF (32% YIELD)

BDS	BD YIELD	LAB	S.U.	MAT.	1ST PASS BASE
100	32	$650	$7	$100	$757
68	22	442	7	68	
46	15	299	7	46	
31	10	201	7	31	
21	7	136	7	21	
14	4	91	7	14	
10	3	65	7	10	
7	2	46	7	7	
5	2	32	7	5	
3	1	20	7	3	
2	1	13	7	2	
1	1	7	7	1	
100	100	2001	84	308	INTRA $2387
		10 MINS/BD	10 MINS/RUN	$1/RUN	

$$\frac{\$1630}{\$2387} = 68\% \quad \text{POTENTIAL IMPROVE}$$

BASELINE
STENCIL PRINTING (65% YIELD)

BDS	BD YIELD	LAB	S.U.	MAT	1ST PASS
100	65	$65	$7	$200	$272
35	23	23	7	70	
12	8	8	7	24	
4	3	3	7	8	
1	1	1	7	2	$439
100	100	100	35	304	INTRA
		1MIN/BD	10 MINS/RUN	$2/RUN	

65c/MIN
$39/HR
100 BD LOT

$$\frac{\$167}{\$439} = 40\% \quad \text{POTENTIAL IMPROVE}$$

BASELINE
FPD COMPONENT FORMING (93% YIELD)

COMPONENTS	COMP YIELD	LABOR	S.U.	1ST PASS BASE
900	837	$1170	$7 →	$1177
63	63	82	7	
	900	1252 2 MINS/ PART	14 10 MINS/ RUN →	$1276
				INTRA

FORMING WILL BE CORRECTED IN 2ND PASS
1% COMPONENT SCRAP/RUN ($4500)

$$\frac{\$\ 82}{\$1276} = 7\%$$ POTENTIAL IMPROVE

BASELINE
FPD COMPONENT TINNING   (100% YIELD)

COMPONENTS	COMP YIELD	LABOR	S.U.	1ST PASS BASE
900	900	$585	$7 →	$591
		1 MIN/PART	10 MIN/RUN	

65¢ /MIN
$39/HR
100 BD LOT

BASELINE
FPD COMPONENT PLACEMENT (100% YIELD)

COMPONENTS   LABOR   S.U.   1ST PASS BASE

900 (FPD) $845 $7 ⟶ $852
8400 (LCC/RTC)

13 MINS/BD   10 MINS/BD

9 FPD/BD - .5 MIN/PART - 4.5 MIN/BD
20 LCC/BD - .1 MIN/PART - 2.0 MIN/BD
65 RTC/BD - .1 MIN/PART 6.4 MIN/BD

1% COMPONENT SCRAP

BASELINE
IR REFLOW (84% YIELD)

BDS	BD YIELD	LAB	S.O.	1% SCRAP COMP	INSP	1ST PASS BASE
100	84	$130	—		$1950 ⟶	$2080
16	16	156	—	$430	312	
	100	$286		430	2262 ⟶	$2978
		2 MINS/BD			30 MINS/BD	INTRA
		15 MINS REWORK/BD				

65c /MIN   2ND PASS IS HAND REWORK
$39/HR   1% SCRAP (PWA)
100 BD LOT

$$\frac{\$\ 898}{\$2975} = 30\% \quad \text{POTENTIAL IMPROVE}$$

BASELINE

PWA CLEANING (21% YIELD)

BDS	BD YIELD	LAB	S.O.	INSP	1ST PASS BASE
100	21	$130	—	$325	$455
79	79	770		257	$1482
	100	$900		582	INTRA

2 MINS/BD
15 MINS RWK/BD

5 MINS/BD

2ND PASS IS HAND REWO

65¢ /MIN
$39/HR
100 BD LO

$$\frac{\$1027}{\$1482} = 69\%$$ POTENTIAL IMPROVE

"INTER" STUDY

CYCLE TIME GOALS

"INTER" STUDY CYCLE TIME GOALS
(MINS/BD)

WORKCELLS	BASELINE "INTRA" CYCLE TIME	GOAL "INTER" CYCLE TIME
STANDOFFS	29.0	0
STENCIL PRINT	11.5	5.2
FDP LEAD FORMING	19.3	19.0
FDP LEAD TINNING	9.1	9.3
COMPONENT PLACEMENT	13.1	15.3
REFLOW	39.2	36.5
CLEANING	24.0	12.0
TOTAL	145.3	97.3

REDUCE CYCLE TIME BY 33%

CYCLE TIMES/BD
(MINS)

WORKCELLS	PROCESS TIME	SET UP TIME	REWORK TIME	INSP
STANDOFF	10	10	20	-
STENCIL PRINTING	1	10	11	-
FPD LEAD FORMING	2	10	10	-
FPD LEAD TINNING	1	10	10	-
COMPONENT PLACEMENT				
(9) FPD .5 MINS.	4.5			
(20) LCC .1 MIN.	2.0	10	10	-
(65) RTC .1 MINS	6.5			
IR REFLOW	2	-	15	30
CLEANING	2	-	15	5
CYCLE TIME/BD	31	50		35
100 BD LOT SIZE	31	.5		35

66.5 MINS

BASELINE
CYCLE TIME - "INTRA"
(LOT SIZE 100 UNITS) (MINUTES)

CYCLES	WORKCELLS	RUN TIME/ BD	PROCESS TIME	SET UP TIME	REWORK TIME	INSPECTION TIME	CYCLE TIME/ BD
12	STANDOFFS	10	1200	600	1100	-	29.0
5	STENCIL PRINTING	1	100	500	550	-	11.5
2	FPD FORMING (9X)	2	1800	10	126	-	19.3
1	FPD TINNING (9X)	1	900	10	-	-	9.1
1	COMPONENT PLACE (94X)	13	1300	10	-	-	13.1
2	JR REFLOW	2	200	-	240	3480 .	39.
2	CLEANING	2	200	-	1300	900	24.0
	100 UNITS (TOTAL 14526)		5700	1130	3316	4380	145.3
	1 UNIT		57.0	11.3	33.2	43.8	

A-29

100% 1ST PASS YIELD	TOTAL				
	66.5/BD	3100	50.0		3500
		31.0	0.5		35.0

Appendix B

Subtask 1: Infrared Reflow

Interoffice Correspondence
TRW Avionics & Surveillance Group

TRW

Subject	Date	From
Detailed Experimental Plan Infrared Reflow (ST10)	16 August 1991	P. CREPEAU

To	cc	Location/Phone
P. Glaser	D. Cavanaugh P. Finkenbinder J. Murray T. Neillo	RC4/1073/3182

I. INTRODUCTION

This IOC presents the detailed experimental plan and procedures for performing the Sub Task 1 experimental procedure. This experiment is designed to identify significant inter-workstation process variables that effect several responses for the infrared reflow work cell. The significant process variables were identified in a "brainstorming" session among several manufacturing and process engineers. Figure 1 presents a cause and effect diagram that identifies the process variables and responses for the infrared reflow work cell. The encircled process variables are those being evaluated in this experiment. The other process variables are intrastation variables that were previously evaluated and reported.

Ranges (or levels) for the process variables were selected based on tolerances that were expected to be encountered on the factory floor. These ranges, the instruments used to measure the variables, and the reference to the source for the ranges are presented in Table 1. Double asterisks identify those process variables being evaluated by this experiment. Responses to be analyzed for the infrared reflow workstation, the instruments used to measure the responses, the specification limits for the responses, and the source for the specification limits are presented in Table 2. The main experimental design is an eight run fractional factorial with seven variables. One reflection is required and will be run.

Table 3 presents the form that will be used for each response evaluated by this main experimental design. A single point experiment is also being designed in which the effect of PWB thickness on solder joint temperature will be determined. It was concluded that this is a single cause and effect relationship that can safely be pulled out of the fractional factorial design.

Emitter Temperatures

Belt Speed

Initial Input Temperature

REFLOW PROCESS
VARIABLES

Air Control

Nitrogen Environment

Humidity

IR REFLOW
RESPONSES

Alignment
Surface Reflectance
Surface Roughness
Heel Fillet Height
Soldered Lead Dewetting
Soldered Lead Volume
Solder Balls
Solder Joint Temperature

PWB Thickness

Tinned Lead Aging

Paste Powder Aging

Paste Thickness

MATERIAL
VARIABLES

Component Placement

Paste Placement

PWB Solder Aging

PWB Plating

Figure 1. Infrared reflow cause and effect diagram.

Table 1. Process variable details.

Process Variable	Measuring Device/ Precision	Variable Range	Specification
*PWB thickness	Dial micrometer/ +/- 0.1-mil	58 to 68 mils	PWB fab drawing
Emitter temperatures	Panel thermocouples +/- 1 deg C	+/- 5 deg C from nominal	Baseline document
Solder joint temp	Mole/ +/- 1 deg C	210+/-2 deg C	MIL-STD 2000
Belt speed	Stop watch and ruler/ +/- 0.01 ft per +/- 0.1 sec	29 in/min	Baseline document
Initial PWB temperature	Thermocouple/ +/- 1 deg C	10 to 30 deg C	Facility requirement
Exhaust air flow	Anemometer/ +/- 1 scfm	10 to 20 scfm	Baseline document
Nitrogen atmosphere	Oxygen analyzer	0 to 3% O_2	Baseline document
Humidity	Diaphragm gauge/ +/- 5%	35 to 65%	Baseline
*Tinned lead aging (except for FPDs)	Steam ager/ 1 minute	0 to 8 hours	Engineering judgment
*Solder paste powder aging	Oven with timer/ +/- 15 minutes	24 hours at 95 deg C	Engineering judgment
*Solder paste deposit thickness	Dial micrometer/ +/- 0.1-in	4/10-mil to 10/14-mil	Engineering judgment
*Component placement (induced offset)	Offset input via robot controller	0 to +3X/+3Y from design	MIL-STD-2000
*Solder paste deposit placement (induced)	Offset input via stencil printer cntr	0 to -3X/-3Y from design	MM 2-1
*PWB plating	Inspection/ +/- 0	Reflowed tin-lead and solder dipped/hot air leveled	TRW design options
*PWB plating aging	Steam ager/ +/- 1 minute	0 to twelve months	Engineering judgment

* Process variables being studied by this experiment.

Table 2. Response variable details.

Response Variable	Measuring Device/ Precision	Specification Limit	Specification
Lead/pad alignment	Microscope with filar +/- 0.1-mil	+/- 2.5 mils from nominal	MIL-STD-2000
	FPD	+/- 5 mils, CL to CL	
	LCC	+/- 8.75 mils CL to CL	
Solder joint reflectance	Visual comparison/ NA	Specular (1) to flat (5)	Engineering judgment
Solder joint finish	Visual comparison/ NA	Smooth (1) to rough (5)	Engineering judgment
Solder heel fillet height	Microscope with filar/ +/- 0.1-mil	0 to 100% of "calf" length	MM 3-23
FPD soldered lead dewetting	Microscope with particle counting grid/NA	0 to 5% of soldered area	MM 3-22
FPD soldered lead solder volume	Visual comparison/ NA	No lead-to-pad fillet extend-ing over top of lead foot and beyond edge	MM 3-21 and MM 3-22
Solder balls	Microscope with filar/ +/- 0.1-mil	0 to 5 mils	MM 5-6
Solder joint temperature	MOLE with thermo-couple/ +/- 1 deg C	Nominal +/- 6 C	MIL-STD-2000

Table 3. Response table with interaction effects.

Random Order Trial Number	Standard Order Trial Number	Response Observed Values	A		B		C		AB		AC		BC		ABC	
			1	2	1	2	1	2	1	2	1	2	1	2	1	2
	1															
	2															
	3															
	4															
	5															
	6															
	7															
	8															
TOTAL																
NUMBER OF VALUES																
AVERAGE																
EFFECT																

II.   MATERIALS AND SUPPLIES

PWB

Qty	P/N	Description
12	786582A	Nominal solder dipped and hot air leveled
12	786582C	Nominal fused tin-lead
2	786582E	Thin fused-tin lead
2	786582F	Thick fused-tin lead

Components

Qty	P/N	Description
48	PB-F86259	Kyocera, 132-pin, 25-mil pitch, leaded package
36	70-02	Diacon, 132-pin, 25-mil pitch, leaded package
504	PB-C85124	20-pin, square, leadless chip carrier
280	PB-44823	28-pin, square, leadless chip carrier
224	IRK32F1-200B	32-pin, rectangular, leadless chip carrier
1064	M55342K06B110BR	Chip resistor
1176	CDR02BX103BKURT	Chip capacitor
168	49BCP	Chip capacitor, CWR06 package style

Solder

QQ-S-571, Sn63, bar
Metech RHF63, virgin

Metech, Inc.
Route 401
Halverson, PA 19520

Metech RHF63, aged powder

Metech, Inc.
Route 401
Halverson, PA 19520

Flux

Kester 1585-MIL

Kester Solder Co.
515 Touhy Ave
Des Plaines, IL 60018-2575

Solvent

Blakosolv 404

Baron Blakeslee, Inc.
2001 N. Janice Avenue
Melrose Park, IL 60160

Isopropyl alcohol

TT-I-335

Stencil

4/10 and 10/14 thicknesses

T-786582-6/1 top and
T-786582-6/2 bottom

<u>Miscellaneous</u>

Palette knife, plastic	Holbein
Shamis, 99-150 cleaning cloth	Affiliated Manufacturers
Bristle brush	
Protective gloves, 96244	Jones Associates

III. **TOOLS AND EQUIPMENT**

General purpose stereo microscope, 0.7x-3x zoom with an American Optical No. 424, 10x-filar eyepiece.

Screen Printer No. 24-ASP
MPM Corp.
10 Forge Park
Franklin, MA 02035

Malcom Viscometer
Austin American Technology
12201 Technology Blvd
Austin, TX 78727

Test Print Pattern Stencil
PIN STNC0001
TRW MEAD
1 Rancho Carmel
San Diego, CA 92128

In-Line Cleaner, CBL-18
Baron-Blakeslee, Inc.
2001 N. Janice Ave.
Melrose Park, IL 60160

Vapo-Kleen Stencil Cleaner,
Model No. 1110187
Universal Electronics, Inc.

Microscan
CyberOptics Corp.
2331 University Ave., SE
Minneapolis, MN 55414

Robotic Workcell
Gelzer Systems
425 Enterprise Drive
Westerville, OH 43081

Steam Aging Cabinet
Mountaingate Engineering
1510 Dell Ave.
Campbell, CA 95008

Infrared Reflow Oven,
Model SMD722
Vitronics Corp.
Forbes Road
Newmarket, NH 03857

Oxygen Analyzer
Engineered Systems and Design
#3 South Tatrall St.
Wilmington, DE 19801

IV.   PROCEDURE

   A.   Machine Certification

      1.   Nitrogen Atmosphere Concentration

         a.   With the SMD722 IR Oven at room temperature and with a normal
              atmospheric environment in it, monitor the oxygen concentration throughout the
              length of the oven and at three locations along its width. (See Figure 2). The
              instrument used to monitor the oxygen concentration is the Engineered Systems
              and Design Oxygen Analyzer.

         b.   After turning on the nitrogen delivery system and allowing it to purge for 15
              minutes, rerun the oxygen concentration per paragraph IV.A.1.a. The oxygen
              concentration must be less than two percent before it is acceptable for a
              'nitrogen on' run.

      2.   IR Reflow Oven Thermal Profile

         a.   Instrument a spare, EMPI, fully populated and reflowed PWB with five
              thermocouples terminated with connectors for the MOLE temperature recording
              instrument. The thermocouple beads must be in intimate contact with the
              surfaces of the solder joints they are monitoring. (See Figure 3 for the location
              of the solder joints under test.)

         b.   Select the profile on the SMD722 IR oven for the 'Digital 1' PWA, and allow
              the oven to stabilize for this setting.

         c.   Turn on the nitrogen flow to the oven at least 15 minutes prior to running
              product.

         d.   Connect the thermocouples to the MOLE, activate the MOLE, and run the
              PWA under test through the IR oven.

         e.   Dump the collected data and observe the maximum temperature attained by the
              coolest of the five thermocouples. If necessary, adjust the belt speed of the IR
              oven and rerun the test until the maximum temperature achieved on the coolest
              of the five thermocouples is 210C +/- 2C. These conditions are the nominal
              reflow parameters for this experiment.

   B.   Eight Run Fractional Factorial Design with Two Replicate Sets and One Reflected Set.

      1.   Setup

         a.   Select twelve 786582A PWBs and serialize them as 1001 through 1012.

         b.   Take SNs 1007 through 1012 from (a) above, and steam age for 8 hrs. Log
              and record the condition of the 786582A, SN 1001 through 1012 PWBs.

         c.   Select twelve 786582C PWBs and serialize them as 1013 through 1024.

         d.   Take SNs 1018 through 1024 from (c), above, and steam age for 8 hrs   Log
              and record the condition of the 786582C, SN 1013 through 1024 PWBs.

Figure 2

Oxygen Sampling Locations
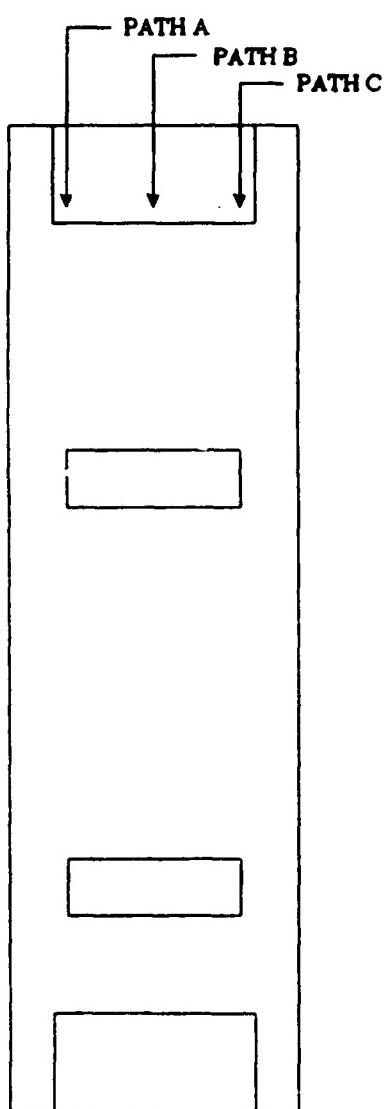
L. ft	PATH A	PATH B	PATH C
0.0			
0.5			
1.0			
1.5			
2.0			
2.5			
3.0			
3.5			
4.0			
4.5			
5.0			
5.5			
6.0			
6.5			
7.0			
7.5			
8.0			
8.5			
9.0			
9.5			
10.0			
10.5			
11.0			
11.5			
12.0			
12.5			
13.0			
13.5			

Figure 3

Thermocouple Attachment Points
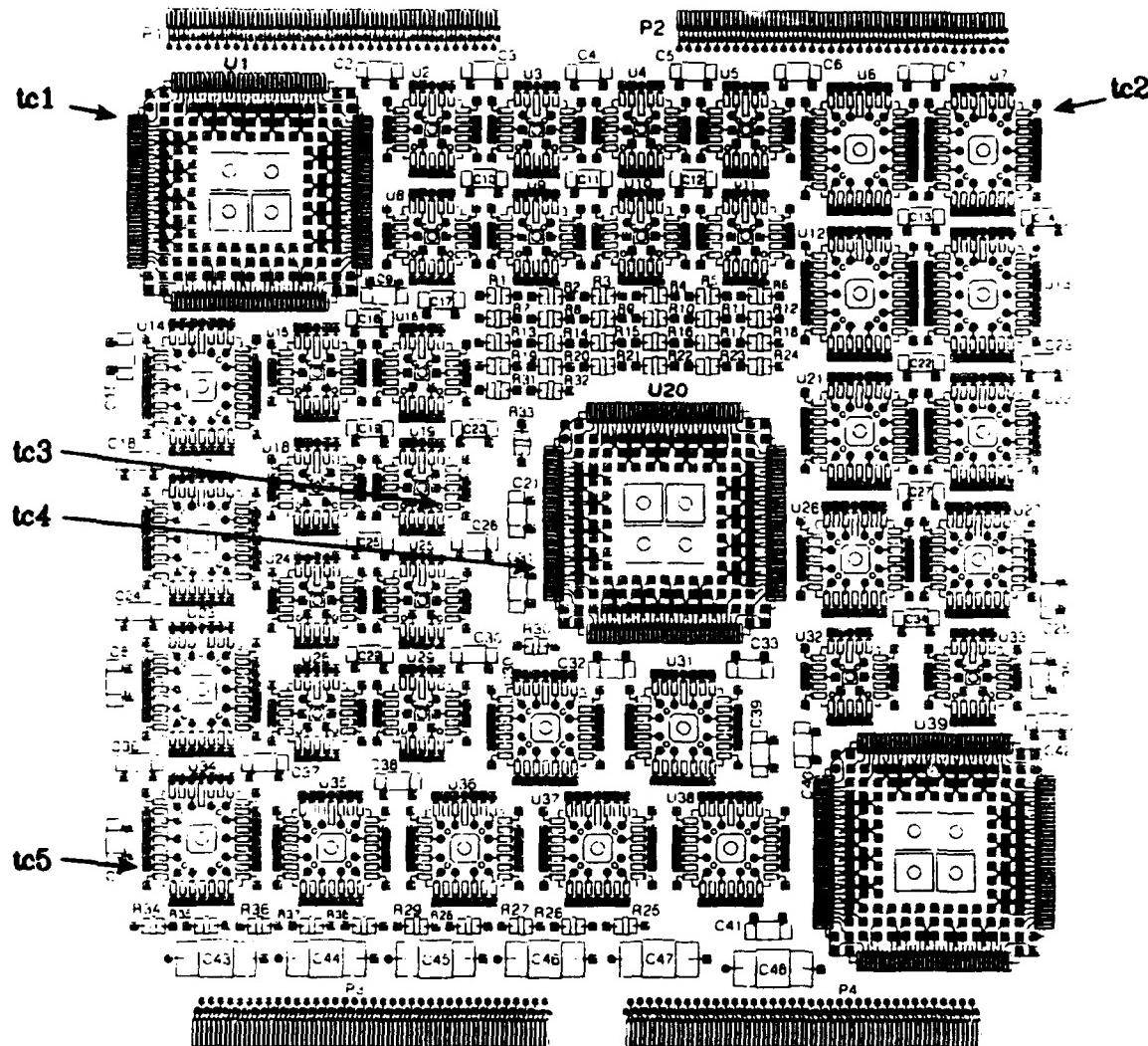
2. Initial Replicate Set

a. The worksheet shown in Table 16 is to be used to run the initial replicate set of eight runs. Column A is assigned to "Solder Paste Stencil Thickness" in mils; subcolumn 1 is for "4/10," subcolumn 2 is for "10/14." Column B is assigned to "Paste Powder Aging" in hours at 95C; subcolumn 1 is for "0," subcolumn 2 is for "24." Column C is assigned to "Tinned Lead Steam Aging" in hours; subcolumn 1 is for "0," subcolumn 2 is for "8." Column AB is assigned to "Paste Deposit Offset" in mils X and Y; subcolumn 1 is for "0", subcolumn 2 is for "-3/-3 mils". Column AC is assigned to "PWB Steam Aging" in hours; subcolumn 1 is for "0," subcolumn 2 is for "8." Column BC is assigned to "Component Offset" in mils X and Y; subcolumn 1 is for "0 mils," subcolumn 2 is for "+3/+3 mils". Column ABC is assigned to "PWB Style" which is either plated and fused or solder dipped and hot air leveled; subcolumn 1 is for "fused," subcolumn 2 is for "air."

b. Run the experimental trials for this initial experiment using the random number sequence listed in the "Random Order Trial Number" column of Table 16.

c. Clean the appropriate, serialized PWBs in the in-line solvent cleaner.

d. Set up the 24-ASP stencil printer with an appropriate reference PWB. Keep in mind that an offset is being introduced at this station (nom. and max. solder paste deposit misregistration) as well as solder paste deposit thicknesses and as well as a solder paste that has an aged solder powder and a paste that has an unaged solder powder that are being printed.

e. Set up the component preparation and placement sides of the Gelzer robot. An offset is being forced at this workcell (nom. and max. component misregistration) as well as steam aged PWBs and components.

f. Set up the CBL-18 in-line cleaner and use the No. 1 cleaning process profile.

g. Select the stencil, PWB, solder paste, and components required for the run identified as random number 1 in Table 20.

h. Stencil print the PWB forcing the desired offset, as required by the test matrix. The coordinate system coincides with the PWB design database.

i. Place the printed PWB in the Gelzer robot load station and form, trim, tin, and place the selected FPD and all other components using either the nominal placement values or the forced placement offset values as specified by the Table 20 matrix. The coordinate system coincides with the PWB design database.

j. Reflow the PWB subassembly in the IR reflow oven under the conditions specified by the Table 20 matrix, and then clean it in the CBL-18 in-line cleaner.

k. Repeat steps (b) through (j), inclusive until all 8 experimental runs have been completed for this initial replicate experiment.

l. Run the tests according to the random number sequence.

3. Reflected Set

a. Using the test parameters and the random order sequence specified by the Table 17 matrix for a reflected run, repeat steps (IV.B.2.b-IV.B.2.k).

3. Second Replicate Set

a. Using the test parameters and the random order sequence specified by the Table 18 matrix for a second replicated run, repeat steps (IV.B.2.b-IV.B.2.k).

C. Single Point Design Set

1. Select two 786582E PWBs and serialize them as 1025 and 1026.

2. Select two 786582F PWBs and serialize them as 1027 and 1028.

3. Set up the 24-ASP. stencil printer. the "prep" and place arms of the Gelzer robot. the SMD-722 IR reflow oven, and the CBL-18 in-line cleaner for nominal processing characteristics.

4. Process the two 786582E and the two 786582F PWBs through the line to yield four assembled and soldered PWBs.

5. Instrument the four PWAs in a manner identical to that used for the IR setup and described in paragraph IV.A.2. See Figure 3 for the thermocouple bead locations.

V. RESPONSE DATA

A. Eight Run Fractional Factorial Design

1. Soldered Component Alignment

a. Measure the fine pitch component lead placement lateral misregistration for each of the 24 experimental runs at the locations listed in Table 4. Use a filar eyepiece on a microscope with a precision of at least 0.1-mil. Figure 4 depicts where the measurements will be made.

b. Measure the 20-pin LCC component termination placement lateral misregistration for each of the 24 experimental runs at the locations listed in Table 5. Use a filar eyepiece on a microscope with a precision of at least 0.1-mil. Figure 5 depicts where the measurements will be made.

c. Measure the 28-pin LCC component termination placement lateral misregistration for each of the 24 experimental runs at the locations listed in Table 6. Use a filar eyepiece on a microscope with a precision of at least 0.1-mil. Figure 5 depicts where the measurements will be made.

d Measure the 32-pin LCC component termination placement lateral misregistration for each of the 24 experimental runs at the locations listed in Table 7. Use a filar eyepiece on a microscope with a precision of at least 0.1-mil. Figure 5 depicts where the measurements will be made.

e. Measure the chip component termination placement lateral and end-to-end misregistration for each of the 24 experimental runs at the locations listed in Table 8. Use a filar eyepiece on a microscope with a precision of at least 0.1-mil. Figure 6 depicts where the measurements will be made.

Notes: a. Pins two and seven on all LCC and FPD patterns are connected to an internal plane of 1-oz/ft2 copper foil.

b. Both pins of both chip capacitor styles are connected to an internal plane of 1-oz/ft2 copper foil.

c. Only one pin of the chip resistors is connected to an internal plane of 1-oz/ft2 copper foil. That pin is the 'left' pin when viewed with the reference designators 'right' reading.

Table 4

Fine pitch device placement misregistration

PWB S/N_____

U 01

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
1			
2			
3			
64			
65			
66			
67			
68			
69			
130			
131			
132			

U 20

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
1			
2			
3			
64			
65			
66			
67			
68			
69			
130			
131			
132			

Figure 4

FPD Lead-to-Pad Offset Depiction
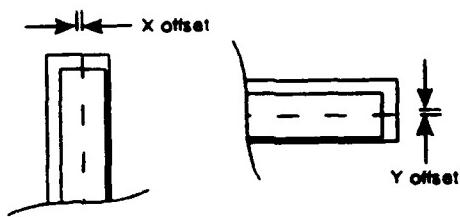
FPD Offset Measurement

Table 5

20-pin LCC device placement misregistration

PWB S/N_____

U 04

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
3			
8			
13			
18			

U 19

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
3			
8			
13			
18			

U 33

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
3			
8			
13			
18			

Table 6

28-Pin LCC placement misregistration

PWB S/N_____

U 22

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
11			
18			
25			

U 30

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
11			
18			
25			

U 35

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
11			
18			
25			

Table 7

32-pin LCC device placement misregistration

PWB S/N_____

U 07

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
13			
20			
29			

U 17

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
13			
20			
29			

U 34

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
13			
20			
29			

Figure 5

LCC Castellation-to-Pad Offset Depiction
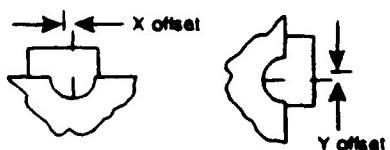
Table 8

Chip device placement misregistration

Chip Component Placement Misregistration

PWB S/N_____

Refer. Designator	X - Offset (mils)	Y - Offset (mils)	Remarks
R 25			
R 30			
R 34			
C 01			
C 21			
C 28			
C 43			
C 47			

Figure 6

Chip Component-to-Pad Offset Depiction
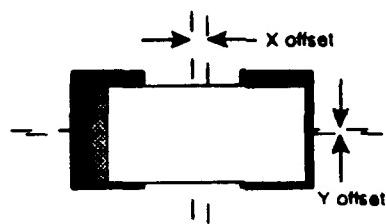
Chip Component Offset Measurement

IV. A. 2. **Reflowed Solder Joint Reflectance**

a. Visually examine the FPD lead solder joints for each of the twenty-four runs at the locations listed in Table 9, and rate the reflectance of the joints by comparing them against the standard shown in Figure 7. Log and record the results.

b. Visually examine the 20-pin LCC solder joints for each of the twenty-four runs at the locations listed in Table 10. and rate the reflectance of the joints by comparing them against the standard shown in Figure 7. Log and record the results.

c. Visually examine the 28-pin LCC solder joints for each of the twenty-four runs at the locations listed in Table 11. and rate the reflectance of the joints by comparing them against the standard shown in Figure 7. Log and record the results.

d. Visually examine the 32-pin LCC solder joints for each of the twenty-four runs at the locations listed in Table 12. and rate the reflectance of the joints by comparing them against the standard shown in Figure 7. Log and record the results.

e. Visually examine the chip component solder joints for each of the twenty-four runs at the locations listed in Table 13 and rate the reflectance of the joints by comparing them against the standard shown in Figure 7. Log and record the results.

Note: Pins 2 and 7 on all LCC and FPD patterns are connected to an internal plane of 1-oz/ft2 copper foil.

Both pins of both chip capacitor styles are connected to an internal plane of 1-oz/ft2 copper foil.

Only one pin of the chip resistor is connected to an internal plane of 1-oz/ft2 copper foil. That pin is the 'left' pin when viewed with reference designators 'right' reading.

Table 9

Fine pitch device solder joint reflectance.

PWB SN:

REF DES	LEAD NO.	REFLECT. RATING	ROUGH RATING	FILLET HEIGHT	COMMENTS
	130				
	131				
	132				
	001				
	002				
	003				
01	007				
	064				
	065				
	066				
	067				
	068				
	069				
	130				
	131				
	132				
	001				
	002				
20	003				
	007				
	064				
	065				
	066				
	067				
	068				
	069				

Table 10

20-pin LCC device solder joint reflectance.

PWB SN:

REF DES	LEAD NO.	REFLECT. RATING	ROUGH RATING	FILLET HEIGHT	COMMENTS
04	001				
	002				
	003				
	004				
	005				
	006				
	007				
	011				
	012				
	013				
	014				
	015				
	016				
19	001				
	002				
	003				
	004				
	005				
	006				
	007				
	011				
	012				
	013				
	014				
	015				
	016				

Table 10. concluded

20-pin LCC device solder joint reflectance.

PWB SN:

REF DES	LEAD NO.	REFLECT. RATING	ROUGH RATING	FILLET HEIGHT	COMMENTS
01	001				
	002				
	003				
	004				
	005				
	006				
	007				
	011				
	012				
	013				
	014				
	015				
	016				

Table 11

28-pin LCC device solder joint reflectance

PWB SN:

REF DES	LEAD NO.	REFLECT. RATING	ROUGH RATING	FILLET HEIGHT	COMMENTS
	002				
	003				
	004				
	005				
22	006				
	007				
	016				
	017				
	018				
	019				
	020				
	021				
	002				
	003				
	004				
	005				
30	006				
	007				
	016				
	017				
	018				
	019				
	020				
	021				

Table 11. concluded

28-pin LCC device solder joint reflectance

PWB SN:

REF DES	LEAD NO.	REFLECT RATING	ROUGH RATING	FILLET HEIGHT	COMMENTS
	002				
	003				
	004				
	005				
35	006				
	007				
	016				
	017				
	018				
	019				
	020				
	021				

Table 12

32-pin LCC device solder joint reflectance.

PWB SN:

REF DES	LEAD NO.	REFLECT. RATING	ROUGH RATING	FILLET HEIGHT	COMMENTS
	002				
	003				
	004				
	005				
	006				
07	007				
	018				
	019				
	020				
	021				
	022				
	023				
	002				
	003				
	004				
	005				
	006				
17	007				
	018				
	019				
	020				
	021				
	022				
	023				

Table 12. concluded

32-pin LCC device solder joint reflectance.

PWB SN:

REF DES	LEAD NO.	REFLECT. RATING	ROUGH RATING	FILLET HEIGHT	COMMENTS
	002				
	003				
	004				
	005				
	006				
34	007				
	018				
	019				
	020				
	021				
	022				
	023				

Table 13

Chip device solder joint reflectance.

Chip Component Placement Misregistration

PWB S/N_____

| Refer. Designator	Reflectance	Roughness	Comments
R 25			
R 30			
R 34			
C 01			
C 21			
C 28			
C 43			
C 47			

MAGNIFICATION 30X
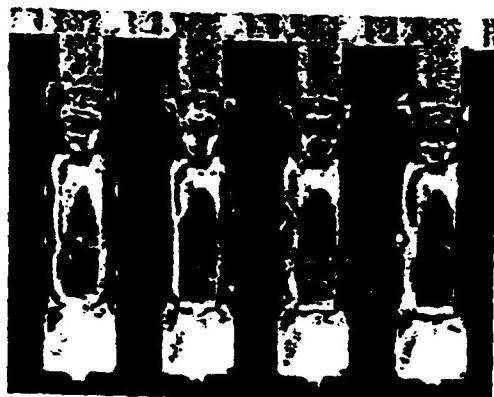
a. (MM 3-4, top) Rank = 1

b. (MM 1-8, middle) Rank = 2

c. (MM 1-6, top) Rank = 3
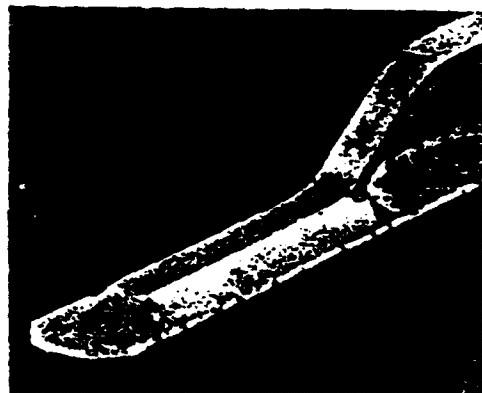
d. (MM 3-22, top) Rank = 4
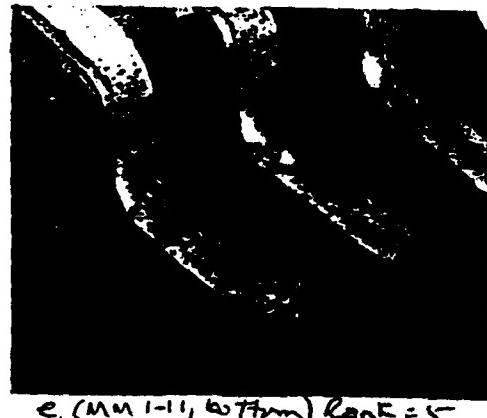
e. (MM 1-11, bottom) Rank = 5

Figure 7. Reflowed solder joint reflectance.

V.   A.   3.   Reflowed Solder Joint Roughness

a.   Visually examine the FPD lead solder joints for each of the twenty-four runs at the locations listed in Table 9 and rate the roughness of the joints by comparing them against the standard shown in Figure 8. Log and record the results.

b.   Visually examine the 20-pin LCC solder joints for each of the twenty-four runs at the locations listed in Table 10, and rate the roughness of the joints by comparing them against the standard shown in Figure 8. Log and record the results.

c.   Visually examine the 28-pin LCC solder joints for each of the twenty-four runs at the locations listed in Table 11 and rate the roughness of the joints by comparing them against the standard shown in Figure 8. Log and record the results.

d.   Visually examine the 32-pin LCC solder joints for each of the twenty-four runs at the locations listed in Table 12 and rate the roughness of the joints by comparing them against the standard shown in Figure 8. Log and record the results.

e.   Visually examine the chip component solder joints for each of the twenty-four runs at the locations listed in Table 13 and rate the roughness of the joints by comparing them against the standard shown in Figure 8. Log and record the results.

a. (MM 3-42, mid-left) Rank=1
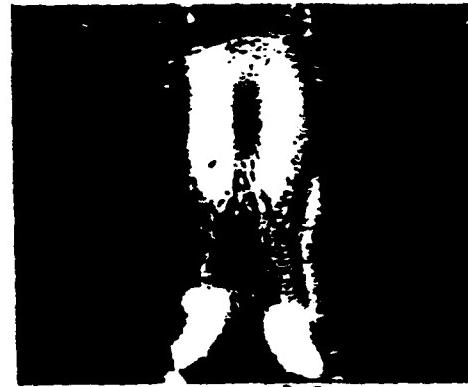
b. (MM 3-41, bt-rt) Rank=2

c. (MM 3-41, bt-lt) Rank=3
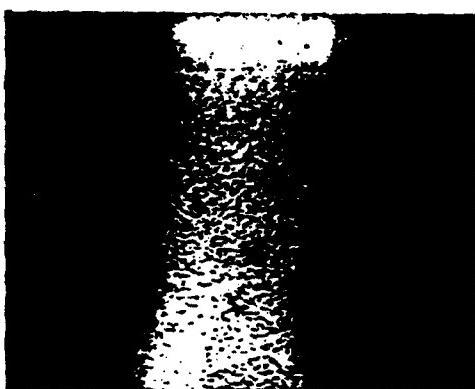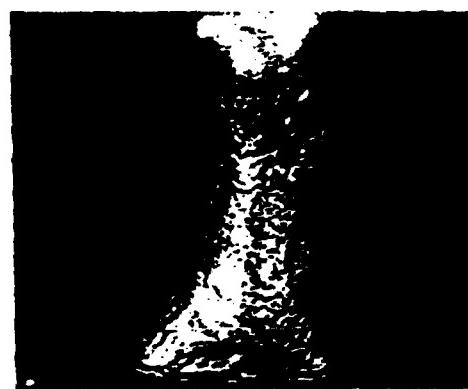
d. (MM 3-41, top-rt) Rank=4
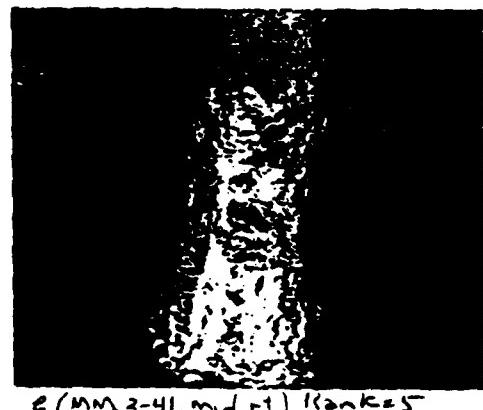
e. (MM 3-41, mid-rt) Rank=5

Figure 8. Reflowed solder joint roughness.

IV.   A.   4.   **FPD Solder Joint Heel Fillet Height**

a.   Measure the length of reflowed solder paste wetting along the "calf" of the FPD lead and report the result as a percent of the total length of the "calf". Make these measurements at the locations listed in Table 9. Log and record the results. See also Figure 9.

5.   **FPD Soldered Lead Dewetting**

a.   Examine the solder joints of the leads of the FPD packages at 10x and map non-wet areas onto a grid. This grid will enable a measurement of the percent of the soldered area of a lead that is non-wet. This mapping shall be accomplished on five leads on each side of each FPD package. These lead numbers are 1, 9, 17, 25, 33, 34, 42, 50, 58, 66, 67, 75, 83, 91, 99, 100, 108, 116, 124, and 132. Log and record the results. See Table 14 and Figure 10.

6.   **FPD Soldered Lead Soldered Volume**

a.   Examine the solder joints of the leads of the FPD packages at 10x and rate the volume of the solder in the solder joints by comparing them against the standards shown in Figure 8. Examine the following leads on all FPD packages on the PWB under test: 1, 9, 17, 25, 33, 34, 42, 50, 58, 66, 67, 75, 83, 91, 99, 100, 108, 116, 124, and 132. Log and record the results. See Table 14 and Figure 11.

7.   **Solder Balls**

a.   Transmission x-ray and visually examine the assembled PWB (PWA) after in-line cleaning, and locate the largest solder ball. If the solder ball is located under a package, remove the package, and measure the diameter of the solder ball using a microscope with a filar eyepiece. See Table 15.

Figure 9

FPD Solder Joint Fillet Height
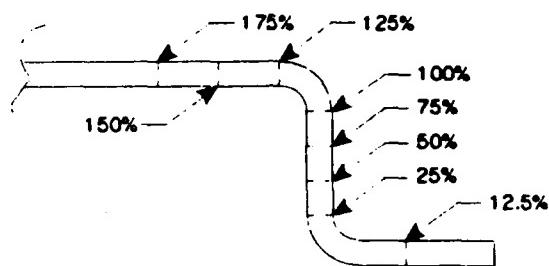
Table 14

FPD Solder Joint Volume and Dewetting

PWB SN:

REF DES	LEAD NO.	SOLDER		COMMENTS
		VOLUME	DE-WETTING	
01	130			
	131			
	132			
	001			
	002			
	003			
	007			
	064			
	065			
	066			
	067			
	068			
	069			
20	130			
	131			
	132			
	001			
	002			
	003			
	007			
	064			
	065			
	066			
	067			
	068			
	069			

Figure 10

FPD Soldered Lead Dewetting
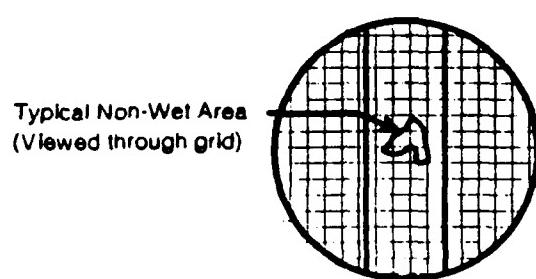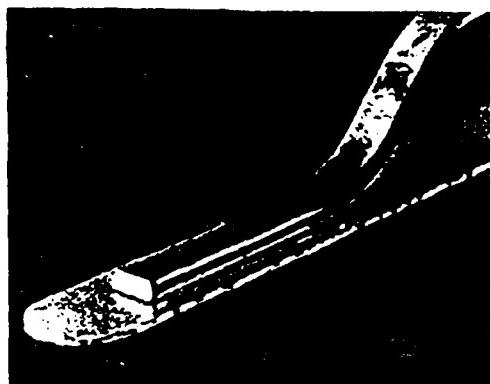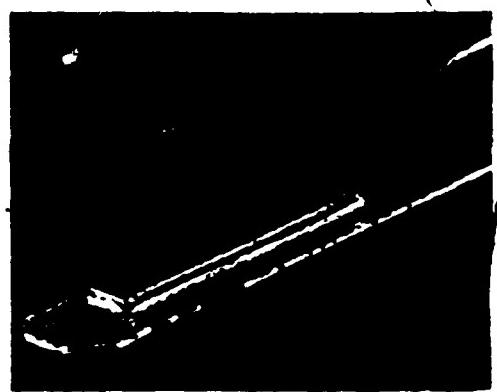
Typical Non-Wet Area
(Viewed through grid)

a. (MM 3-21, bot   Rank=1

b. (MM 3-21, bot mid) Rank=2

MAGNIFICATION 8X
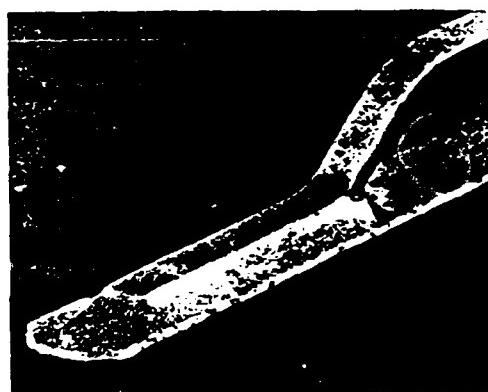
c. (MM 3-21, top) Rank=3
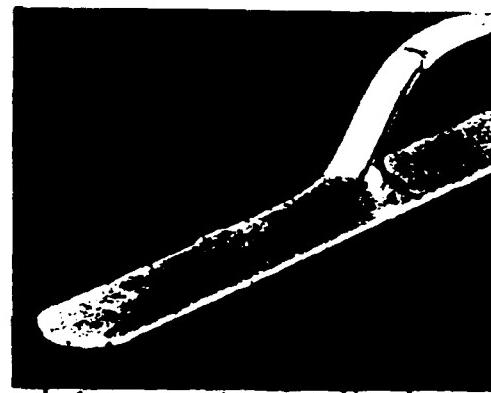
d. (MM 3-22, bot mid) Rank=4

e. (MM 3-22, bot) Rank=5

Figure 11.   Reflowed solder joint volume.

V.   A.   7.   a.   (cont'd)

If the solder ball is not hidden from view, use the microscope with the filar-eyepiece to measure the diameter of the solder ball directly. Log and record the results.

B.   Single Point Design

1.   Solder Joint Temperature

a.   Measure and record the thicknesses of the four PWBs. Take this measurement over the dielectric at each of the four corners and the center of the PWBs.

b.   Mount five thermocouples on each of the two 786582E and two 786582F PWAs on the solder joints at U01-01, U07-29, U19-14, U20-24 and U34-12.

c.   Select one of the four PWAs and connect its thermocouples to the MOLE.

d.   Run this PWA through the IR reflow oven under nominal conditions (with the nitrogen 'on'). Log and record the temperature profiles.

e.   Repeat steps V.B.1.c through V.B.1.d until all four boards have been profiled.

VI.   DATA REDUCTION

Using the data gathered by this experiment, the response sheets typified by Table 3 will be completed for each response; and significant interstation process variables will be identified.

Additional statistical analyses of the data using analysis of variance (ANOVA) techniques will yield variability, experimental error, and process capability indices data.

Table 15

Solder Ball Response

PWB SerNo. Max. Ball Dia, mils   Location

Table 16
Replicate No. 1 Experiment Recipe

Random Order Trial Number	Standard Order Trial Number	PWB Serial Number	A Paste Stencil Thickness mils		B Paste Powder Aging hours/95 C		C Tin Lead Steam Aging hrs		AB Paste Deposit Offset, mils, included, X/Y		AC PWB Steam Aging hours		BC Component Offset, mils, included, X/Y		ABC PWB Style		RESPONSE
			1	2	1	2	1	2	1	2	1	2	1	2	1	2	
10	1	1007	4/10		0		0			-3/-3		8		+3/+3	fused		
08	2	1001	4/10		0			8		-3/-3	0		0			air	
14	3	1008	4/10			24	0		0			8	0			air	
03	4	1002	4/10			24		8	0		0			+3/+3	fused		
05	5	1003		10/14	0		0		0		0			+3/+3		air	
12	6	1009		10/14	0			8	0			8	0		fused		
15	7	1004		10/14		24	0			-3/-3	0		0		fused		
04	8	1010		10/14		24		8		-3/-3		8		+3/+3		air	

Table 17
Reflection No. 1 Experiment Recipe

Random Order Trial Number	Standard Order Trial Number	PWB Serial Number	A Paste Stencil Thickness mils		B Paste Powder Aging hours/95 C		C Tin Lead Steam Aging hrs		AB Paste Deposit Offset, mils, included, X/Y		AC PWB Steam Aging hours		BC Component Offset, mils, included, X/Y		ABC PWB Style		RESPONSE
			1	2	1	2	1	2	1	2	1	2	1	2	1	2	
04	1	1005	█	10/14	█	24	█	8	0	█	0	█	0	█	█	air	
01	2	1011	█	10/14	█	24	0	█	0	█	█	8	█	+3/+3	fused	█	
02	3	1006	█	10/14	0	█	█	8	█	-3/-3	0	█	█	+3/+3	fused	█	
08	4	1012	█	10/14	0	█	0	█	█	-3/-3	█	8	0	█	█	air	
07	5	1019	4/10	█	█	24	█	8	█	-3/-3	█	8	0	█	fused	█	
05	6	1013	4/10	█	█	24	0	█	█	-3/-3	0	█	█	+3/+3	█	air	
03	7	1020	4/10	█	0	█	█	8	0	█	█	8	█	+3/+3	█	air	
06	8	1014	4/10	█	0	█	0	█	0	█	0	█	0	█	fused	█	

Table 18
Replicate No. 2 Experiment Recipe

Random Order Trial Number	Standard Order Trial Number	PWB Serial Number	A Paste Stencil Thickness mils		B Paste Powder Aging hours/95 C		C Tin Lead Steam Aging hrs		AB Paste Deposit Offset, mils, included, X/Y		AC PWB Steam Aging hours		BC Component Offset, mils, included, X/Y		ABC PWB Style		RESPONSE
			1	2	1	2	1	2	1	2	1	2	1	2	1	2	
09	1	1021	4/10		0		0			-3/-3		8		+3/+3	fused		
07	2	1015	4/10		0			8		-3/-3	0		0			air	
11	3	1022	4/10			24	0		0			8	0			air	
06	4	1016	4/10			24		8	0		0			+3/+3	fused		
01	5	1017		10/14	0		0		0		0			+3/+3		air	
16	6	1023		10/14	0			8	0			8	0		fused		
13	7	1018		10/14		24	0			-3/-3	0		0		fused		
02	8	1024		10/14		24		8		-3/-3		8		+3/+3		air	

Appendix C

Subtask 2:   Fine Pitch Device Lead Tinning

SUBTASK 2

FINE PITCH DEVICE LEAD TINNING

This document presents the detailed experimental plan and procedures for performing the Sub Task 2 experimental procedure. This experiment is designed to identify significant inter-workstation process variables that affect several responses for the fine pitch device (FPD) lead tinning work cell. The significant process variables were identified in a "brainstorming" session among several manufacturing and process engineers. Figure 1 presents a cause and effect diagram that identifies the process variables and responses for the FPD lead tinning work cell. Those process variables that are being evaluated in this experiment have been encircled. The process variables that are not encircled are intrastation variables that were previously evaluated and reported.

Ranges (or levels) for the process variables were selected based on tolerances that were expected to be encountered on the factory floor. These ranges, the instruments used to measure the variables, and the reference to the source for the ranges are presented in Table 1. Double asterisks identify those process variables being evaluated by this experiment. Responses to be analyzed for the FDP lead tinning workstation, the instruments used to measure the responses, the specification limits for the responses, and the source for the specification limits are presented in Table 2. This experimental design is a full factorial with three variables. No reflection is required. One replicate will be run, however.

Table 3 presents the form that will be used for each response evaluated by this experimental design. Columns AB, AC, BC, and ABC will be used for experimental error measurements.
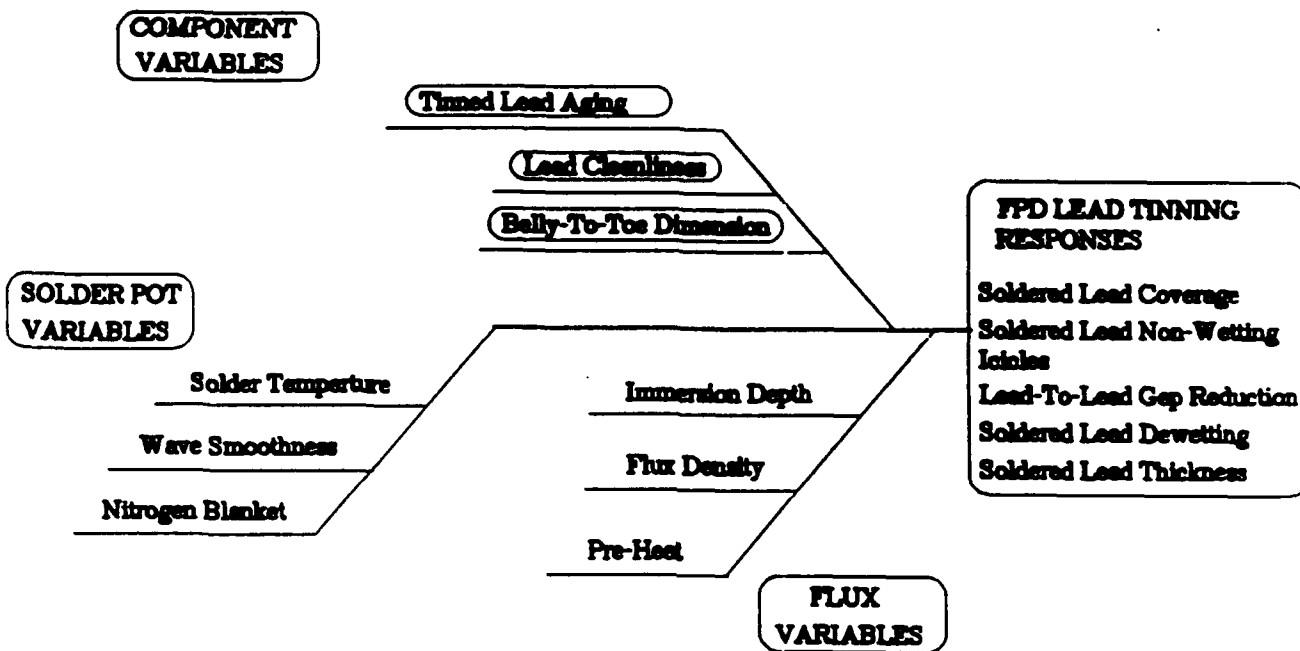
Figure 1. FPD component tinning cause and effect diagram.

Table 1. Process variable details.

Process Variable	Measuring Device/ Precision	Variable Range	Specification
**Lead aging	Steam aging cabinet/ +/- 1 minute	0 to 8 hours (0 to 12 mos.)	Engineering judgment
**Lead cleanliness	10% soln. of oil/ +/- 1%	Clean to contaminated	Engineering judgment
**Belly-to-toe dimension	Microscan/ +/- 0.15 mil	4 to 12 mils	TRW cleaning study
"Calf" immersion in flux	Microscope with filar/ +/- 0.2-mil	0 to 100%	Baseline document
Flux density	Sensby sp gr system/ +/- 0.001	0.885 to 0.895	Baseline document
Solder temperature	Robot controller/ +/- 1 deg F	490 to 510 deg F	MIL-STD-2000
Wave smoothness	Visual	0 to minor turbulence	Baseline document
Nitrogen flow	Flow meter +/- 1 scfh	0 to 100 scfh	Baseline document

Table 2. Response variable details.

Response Variable	Measuring Device/ Precision	Specification Limit	Specification
Solder coverage at "calf"	Microscope with filar/ +/- 0.2-mil	25% to 100% of lead below knee (none at knee bend)	MM 1-6, 1-7
Solder thickness at mid- "calf"	Microscope with filar/ +/- 0.2-mil (cross section)	0.1 to 1 mil	Engineering judgment
Non-wet solder surface	Microscope with particle counting grid/NA	0 to 5% of area	MM 1-9
De-wet solder surface	Microscope with particle counting grid/NA	0 to 5% of area	MM 1-9
Icicles	Microscope with filar/ +/- 0.2-mil	0 to 10 mils	MM 1-9
Lead-to-lead gap reduction	Microscope with filar/ +/- 0.2-mil	0 to 10 mils	Engineering judgment

Table 3. Response table with interaction effects.

Random Order Trial Number	Standard Order Trial Number	Response Observed Value	A		B		C		AB		AC		BC		ABC	
			1	2	1	2	1	2	1	2	1	2	1	2	1	2
	1															
	2															
	3															
	4															
	5															
	6															
	7															
	8															
TOTAL																
NUMBER OF VALUES																
AVERAGE																
EFFECT																

Serial number/Process Variable Relationship Matrix

Serial Number	Belly-to-Toe Dimension		Lead Aging (Steam Aged)		Lead Cleanliness		Run Number	
	4 mils	12 mils	0	12 mos.	Clean	Contam.	Initial	Replicat.
KYO ST2001	XX		XX		XX		1	
KYO ST2002	XX		XX		XX			1
KYO ST2003	XX		XX			XX	2	
KYO ST2004	XX		XX			XX		2
KYO ST2005	XX			XX	XX		3	
KYO ST2006	XX			XX	XX			3
KYO ST2007	XX			XX		XX	4	
KYO ST2008	XX			XX		XX		4
KYO ST2009		XX	XX		XX		5	
KYO ST2010		XX	XX		XX			5
KYO ST2011		XX	XX			XX	6	
KYO ST2012		XX	XX			XX		6
KYO ST2013		XX		XX	XX		7	
KYO ST2014		XX		XX	XX			7
KYO ST2015		XX		XX		XX	8	
KYO ST2016		XX		XX		XX		8

Figure 2

Robotic Workcell, [response name] experimental design matrix

Initial Run

Proposed/Actual Variable States

Random Sequence Number	Run Number	Belly-to-Toe Dimension		Lead Aging		Lead Cleanliness		EXPERIMENTAL ERROR
		Prop.	Act.	Prop.	Act.	Prop.	Act.	
7	KYO 1 ST2001	4 mls		0		Clean		
2	KYO 2 ST2003	4 mls		0		Cont.		
5	KYO 3 ST2005	4 mls		12 mos		Clean		
6	KYO 4 ST2007	4 mls		12 mos		Cont.		
4	KYOC 5 ST2009	12 mls		0		Clean		
8	KYOC 6 ST2011	12 mls		0		Cont.		
3	KYOC 7 ST2013	12 mls		12 mos		Clean		
1	KYOC 8 ST2015	12 mls		12 mos		Cont.		

Figure 3

Robotic Workcell, [response name] experimental design matrix

Replication		Proposed/Actual Variable States								
Random Sequence Number	Run Number	Belly-to-Toe Dimension		Lead Aging		Lead Cleanliness				
		Prop.	Act.	Prop.	Act.	Prop.	Act.			
5	KYO 1 ST2002	4 mils		0		Clean				
1	KYO 2 ST2004	4 mils		0		Cont.				
2	KYO 3 ST2006	4 mils		12 mos		Clean				
4	KYO 4 ST2008	4 mils		12 mos		Cont.				
6	KYOC 5 ST2010	12 mils		0		Clean				
3	KYOC 6 ST2012	12 mils		0		Cont.				
8	KYOC 7 ST2014	12 mils		12 mos		Clean				
7	KYOC 8 ST2016	12 mils		12 mos		Cont.				

EXPERIMENTAL ERROR

Figure 4

II. MATERIALS AND SUPPLIES

<u>PWB</u> - (None required)

<u>Components</u>

<u>Qty</u>	<u>P/N</u>	<u>Description</u>
16	PB-F86259	Kyocera, 25 mil pitch, 132 lead chip carrier.

<u>Solder</u>

QQ-S-571, Sn63, bar   Virgin Alloy

<u>Flux</u>

Kester 185   Kester Solder Co.
                                  515 Touhy Ave
                                  Des Plaines, IL 60018-2575

<u>Stencil</u> - (None required)

<u>Miscellaneous</u>

96244 Protective gloves   Jones Associates

Machine Cutting Oil   Oil, petroleum, for contaminating leads

<u>Solvent</u>

Genosolv DMSA   Baron Blakeslee, Inc.
                                     2001 N. Janice Avenue
                                     Melrose Park, IL 60160

Isopropyl Alcohol   TT-I-735

III. TOOLS AND EQUIPMENT

General purpose stereo microscope, 0.7x-3x zoom with an American Optical No. 424, 10x-filar eyepiece.

Dial Micrometer, Lufkin

Polaroid camera with macrolens (to assist in evaluation of solderability).

Steam Aging Cabinet

Mountain Gate Engineering
1510 Dell Ave.
Campbell, CA 95008

Robotic Workcell, Model 1312

Gelzer Systems
425 Enterprise Drive
Westerville, OH 43081

IV. PROCEDURE

NOTE: Refer to the "SERIAL NUMBER/PROCESS VARIABLE RELATIONS... MATRIX" (see figure #2) when serializing the FPD packages to determine which variables are forced for each serial number.

1. Select sixteen Kyocera, 132-pin fine pitch device (#PB-F86259) packages and place a black ink dot on the lid of all sixteen packages to indicate pin #1 (see figure #5). Serialize them as KYO ST2001 through ST2016.

2. Locate the following eight FPD package serial numbers and form their leads to the minimum "belly-to-toe" dimensions (4 mils). Log and record the serial numbers of these packages and their initial belly-to-toe measurements in table 4.

Pin 132   Pin 100

Pin 1 Indicator

Pin 1   Pin 99

KYO
ST2001

Pin 33   Pin 67

NOTE: Pin count runs counterclockwise
around package when viewed
from the package top.

Typical Serial
Number location

Pin 34   Pin 66

FIGURE #5

This edge faces the robot arm

4	3	2	1
8	7	6	5
12	11	10	9
16	15	14	13
20	19	18	17

Preparation side elevator feeder
tray #1 pocket locations and
numbering scheme.
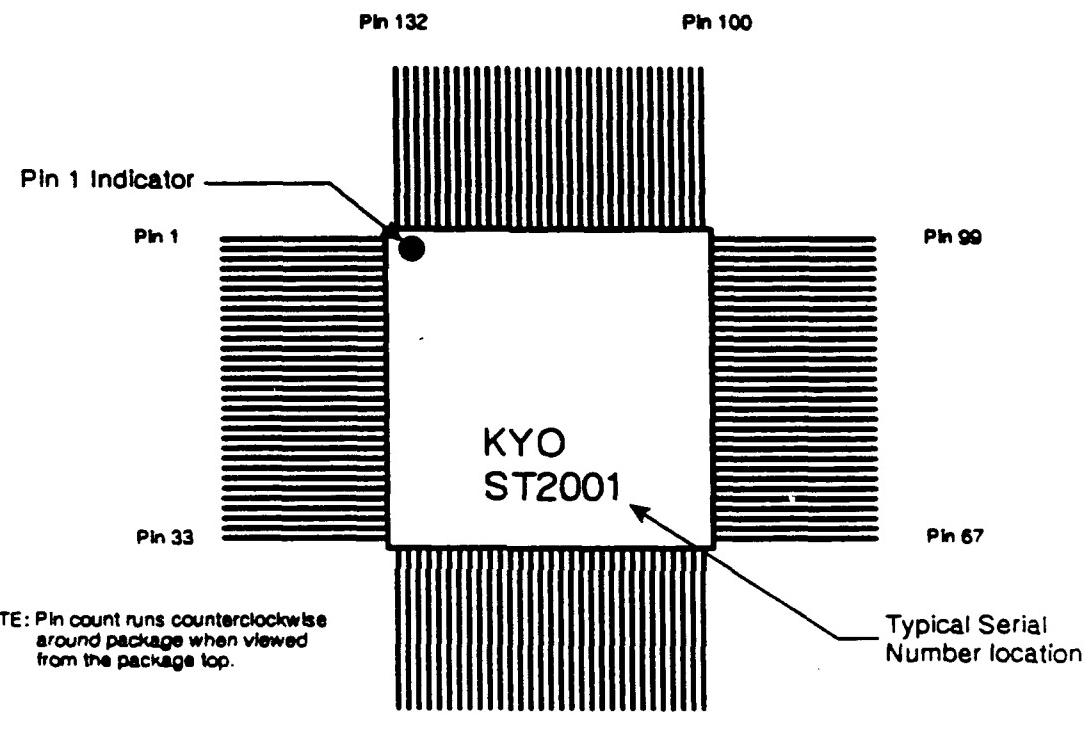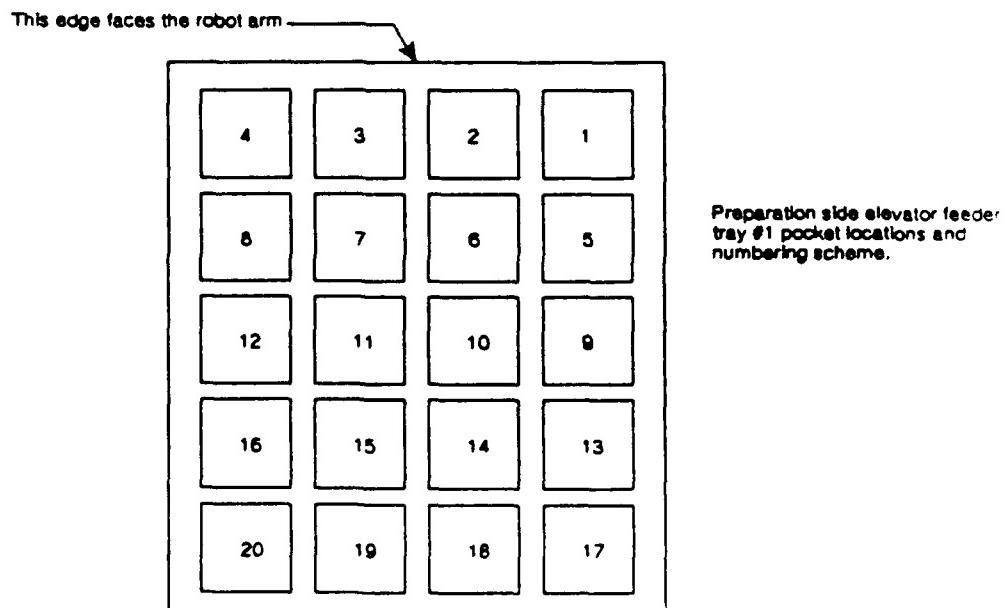
FIGURE #6
C-13

FPD Serial Numbers

KYO ST2001   KYO ST2005
KYO ST2002   KYO ST2006
KYO ST2003   KYO ST2007
KYO ST2004   KYO ST2008

3. Locate the following eight FPD package serial numbers and form their leads to the maximum "belly-to-toe" dimensions (12 mils). Log and record the serial numbers of these packages and their initial belly-to-toe measurements in table 4.

FPD Serial Numbers

KYO ST2009   KYO ST2013
KYO ST2010   KYO ST2014
KYO ST2011   KYO ST2015
KYO ST2012   KYO ST2016

4. Locate the following eight FPD package serial numbers and subject them to the steam aging process for a period of eight (8) hours.

FPD Serial Numbers

KYO ST2005   KYO ST2013
KYO ST2006   KYO ST2014
KYO ST2007   KYO ST2015
KYO ST2008   KYO ST2016

5. Prepare the lead contaminating solution by adding 10 ml of machine cutting oil (or equivalent) to 90 ml of isopropyl alcohol. Stir this solution gently until it appears to be homogeneous. Cover the solution tightly until needed.

6. Gently stir the contaminating solution prepared in step #5. Locate the following eight FPD package serial numbers and dip their leads into the contaminating solution up to the top of the lead knee. Remove the excess contaminant by placing the soiled devices on a soft lint free absorbant wipe supported underneath by flat firm surface.

FPD Serial Numbers

KYO   ST2003   KYO   ST2011
KYO   ST2004   KYO   ST2012
KYO   ST2007   KYO   ST2015
KYO   ST2008   KYO   ST2016

7. Create one worksheet, similar to the one shown in Table 3, for each of the six responses listed in Table 2 that are to be monitored (see figures #3 & #4). Column A is assigned to "belly-to-toe" dimension; subcolumn 1 is for minimum length; subcolumn 2 is for maximum length. Column B is assigned to "lead aging;" subcolumn 1 is for the as received condition; subcolumn 2 is for the aged condition. Column C is assigned to "lead cleanliness;" subcolumn 1 is for the uncontaminated condition; subcolumn 2 is for the contaminated condition. The remaining columns are for experimental error determinations.

8. Run the experiment trials using the random number sequence as listed in the "Random Sequence Number" column of figure #3.

9. Set up the component preparation side of the Gelzer robotic workcell minus the part forming function and load the tinning program "TIN.BBF."

10.	Place the appropriate 132-pin FPD packages into the preparation elevator tray #1 in accordance with the **random sequence order number** and starting with pocket #1 (see figure #6). With the feeder tray oriented as shown in figure 6, place the pin #1 indicator of each FPD in the upper left hand corner of the feeder pockets. Tin, clean and inspect the leads of the first two (2) or three (3) devices.

11.	Take some preliminary measurements to confirm that no other <u>significant</u> variables are affecting the process. Stop and contact the cognizant engineer if there appears to be any undocumented outside influences in the process.

12.	Complete the balance of the initial experimental run as directed by the specific response worksheets.

13.	Rerun the experimental matrix in accordance with the random sequence numbers listed in the "Random Sequence Number" column of figure #4. This will result in a replicate set of data to aid in statistical analyses of the *experiment*.

## V.	RESPONSE DATA

A.	Solder Coverage

1.	The solder coverage shall be quantified as a percentge of lead solder wetting where 100% coverage is defined as solder wetting up to, but not into, the lead knee. Use a microscope to make these measurements and enter this data into table #5. The leads designated for data collection and the measurement conventions are delineated in table #5.

B.   Non-Wet Solder Surface

1.   Examine the soldered lead surfaces of the formed and tinned FPD packages for evidence of solder non-wetting. Map any non-wet areas onto a grid and record this information as prompted in table #6. The grid will enable a measurement of the percent of the tinned area of a lead that is non-wet.

C.   Dewetted Solder Surface

1.   Examine the soldered lead surfaces of the formed and tinned FPD packages for evidence of solder dewetting. Map any dewetted areas onto a grid and record this information as prompted in table #7. The grid will enable a measurement of the percent of the tinned area of a lead that is dewetted.

D.   Icicles

1.   Visually scan the formed and tinned leads of each FPD package for evidence of icicling. Count the total number of icicles encountered for each side of the FPD package and record this information in table #8. Identify the lead that represents the worst case of icicling for each side of the package. Use a filar eyepiece on a microscope to measure the length of that worst case icicle to a precision of 0.2-mil, maximum and record this information in table #8.

NOTE: Do not confuse icicling with toe burrs. An icicle is formed purely from the solder on the lead. Contact the cognizant engineer for clarification if any doubt exist as to whether a suspected icicle is truly that or a toe burr (See table #8).

E.   Lead-to-Lead Gap Reduction

1.   Visually scan the formed and tinned leads of each FPD package for evidence of lead-to-lead gap reduction. Identify all lead-to-lead gap reductions that result in a lead gap of less than (<) 5 mils and record the number of occurances for each side of the FPD package as prompted by table #9. Identify the lead-to-lead gap that represents the worst case of gap reduction due to solder for each side of the FPD package and record this data in table #9. The measurement convention is delineated in a diagram located with this table. Use a filar eyepiece on a microscope to measure that worst case gap reduction to a precision of 0.2-mil, maximum.

F.   Solder Thickness at Calf

1.   After all other response data have been gathered, microsection the leads of the FPD packages and measure the thickness of the solder at the mid-"calf" sections of the formed and tinned leads on each side of each package. The specific leads to be measured are delineated in table #10. Record all pertinent data in this table. The average thickness of the solder coating shall be calculated in accordance with the diagram located with table #10.

I.   DATA REDUCTION

Using the data gathered by this experiment, the response sheets typified by Table 3 will be completed for each response; and significant interstation process variables will be identified.

Additional statistical analyses of the data using analysis of variance (ANOVA) techniques will yield variability, experimental error, and process capability indices data.

Table #4

Initial <u>Belly-to-Toe</u> data collection sheet
(Use one sheet for all devices)
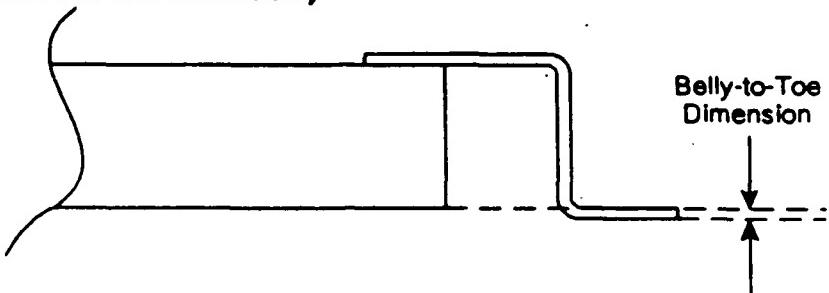
Serial Number	Avg Belly-to-Toe Dimension				Avg Dim of All Four Sides
	Side 1	Side 2	Side 3	Side 4	
KYO ST2001					
KYO ST2002					
KYO ST2003					
KYO ST2004					
KYO ST2005					
KYO ST2006					
KYO ST2007					
KYO ST2008					
KYO ST2009					
KYO ST2010					
KYO ST2011					
KYO ST2012					
KYO ST2013					
KYO ST2014					
KYO ST2015					
KYO ST2016					

Table #5

Solder Coverage data collection sheet
(One sheet for each device)

Device serial number _____

175% — 150% — 125% — 100% — 75% — 50% — 25% — 12.5%

Lead Numbers
(Measure these leads as indicated above)

Side	Lead Numbers							
1	01___	02___	03___	avg___	16___	17___	18___	avg___
			31___	32___	33___	avg___		
2	34___	35___	36___	avg___	49___	50___	51___	avg___
			64___	65___	66___	avg___		
3	67___	68___	69___	avg___	82___	83___	84___	avg___
			97___	98___	99___	avg___		
4	100___	101___	102___	avg___	115___	116___	117___	avg___
			130___	131___	132___	avg___		

Table #6

Non-Wetting data collection sheet
(One sheet for each device)
Device serial number_____

Typical Non-Wet Area
(Viewed through grid)
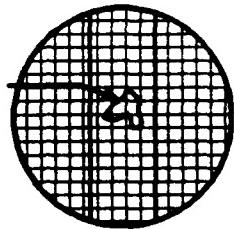
| #	Side 1		Side 2		Side 3		Side 4	
	Lead Number	% Non-wet	Lead Number	% Non-wet	Lead Number	% Non-wet	Lead Number	% Non-wet
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								
33								

Table #7

De-Wetting data collection sheet
(One sheet for each device)
Device serial number_____

Typical De-Wet Area
(Viewed through grid)

#	Side 1		Side 2		Side 3		Side 4	
	Lead Number	% De-wet	Lead Number	% De-wet	Lead Number	% De-wet	Lead Number	% De-wet
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								
33								

Table #8

Icicle data collection sheet
(Use one sheet for all devices)

Measurements are to be in mils
(Thousandths of an inch)

Icicle Dimension
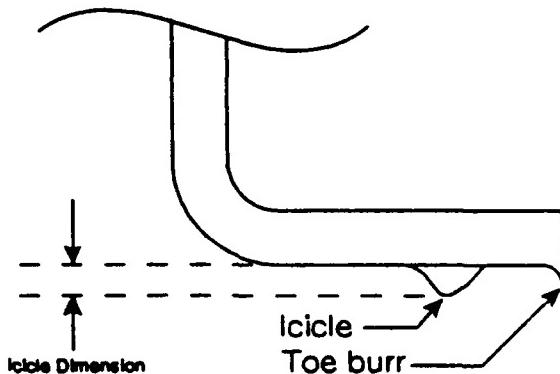
Icicle ———
Toe burr ———

| Serial Number | Icicle Count and Worst Case Dimension | | | | | | | | Worst Case Icicle For All 4 Sides |
| | Side 1 | | Side 2 | | Side 3 | | Side 4 | | |
	Icicle Count	Worst Case Dim.	Icicle Count	Worst Case Dim.	Icicle Count	Worst Case Dim.	Icicle Count	Worst Case Dim.	
KYO ST2001									
KYO ST2002									
KYO ST2003									
KYO ST2004									
KYO ST2005									
KYO ST2006									
KYO ST2007									
KYO ST2008									
KYO ST2009									
KYO ST2010									
KYO ST2011									
KYO ST2012									
KYO ST2013									
KYO ST2014									
KYO ST2015									
KYO ST2016									

Table #9

Lead-to-Lead Gap Reduction data collection sheet
(Use one sheet for all devices)

Gap reduction due to solder

Measurements are to be in mils
(Thousandths of an inch)

Gap Reduction Count and Worst Case Dimension									Worst Case For All 4 Sides
	Side 1		Side 2		Side 3		Side 4		
Serial Number	Count	Worst Case Dim	Count	Worst Case Dim	Count	Worst Case Dim.	Count	Worst Case Dim.	
KYO ST2001									
KYO ST2002									
KYO ST2003									
KYO ST2004									
KYO ST2005									
KYO ST2006									
KYO ST2007									
KYO ST2008									
KYO ST2009									
KYO ST2010									
KYO ST2011									
KYO ST2012									
KYO ST2013									
KYO ST2014									
KYO ST2015									
KYO ST2016									

Table #10

Solder Thickness data collection sheet
(One sheet for each device)

Device serial number _____

Cross Sectional View

Lead

Measurement A

Measurement B

Solder Coating

Solder Thickness = (A+B) ÷ 2

Lead Numbers
(Measure these leads as indicated above)

Side				avg
1	01 ___	09 ___	17 ___	25 ___	33 ___ avg ___
2	34 ___	42 ___	50 ___	58 ___	66 ___ avg ___
3	67 ___	75 ___	83 ___	91 ___	99 ___ avg ___
4	100 ___	108 ___	116 ___	124 ___	133 ___ avg ___

Appendix D

Subtask 3:
Component Standoff
Printed Wiring Assembly Cleaning

Interoffice Correspondence
TRW Avionics & Surveillance Group

7RW

91.Q602.PCC.ST3.1

Subject	**Date**	**From**
Detailed Experimental Plan Component Standoff (ST31)	19 August 1991	P. CREPEAU

To	**cc**	**Location/Phone**
P. Glaser	D. Cavanaugh P. Finkenbinder J. Murray T. Neillo	RC4/1073/3182

I. INTRODUCTION

This IOC presents the detailed experimental plans and procedures for performing the Subtask 3, Part 1 experimental procedure. This experiment is designed to identify significant inter-workstation process variables that effect several responses for the Component Stand-Off workcell.

The significant process variables were identified in a 'brain storming' session among several manufacturing and process engineers. Figure 1 presents a cause and effect diagram that identifies the process variables and responses for the Component Stand-Off workcell. The encircled process variables are those being evaluated in this experiment. The unenclosed process variables are intra-station variables that were previously evaluated and reported.

Ranges (or levels) for the process variables were selected based on tolerances that were expected to be encountered on the factory floor. These ranges, the instruments used to measure the variables, and the reference to the source for the ranges are presented in Table 1. Asterisks identify those process variables being evaluated by this experiment. The response to be analyzed for the Component Stand-Off workstation, the instrument used to measure the response, the specification limit for the response, and the source for the specification limits are presented in Table 2. This experimental design is a fractional factorial with seven process variables. One reflection is required to resolve potential interaction effects. One replicate will also be run. Table 3 presents the form that will be used for the response evaluated by this experimental design.
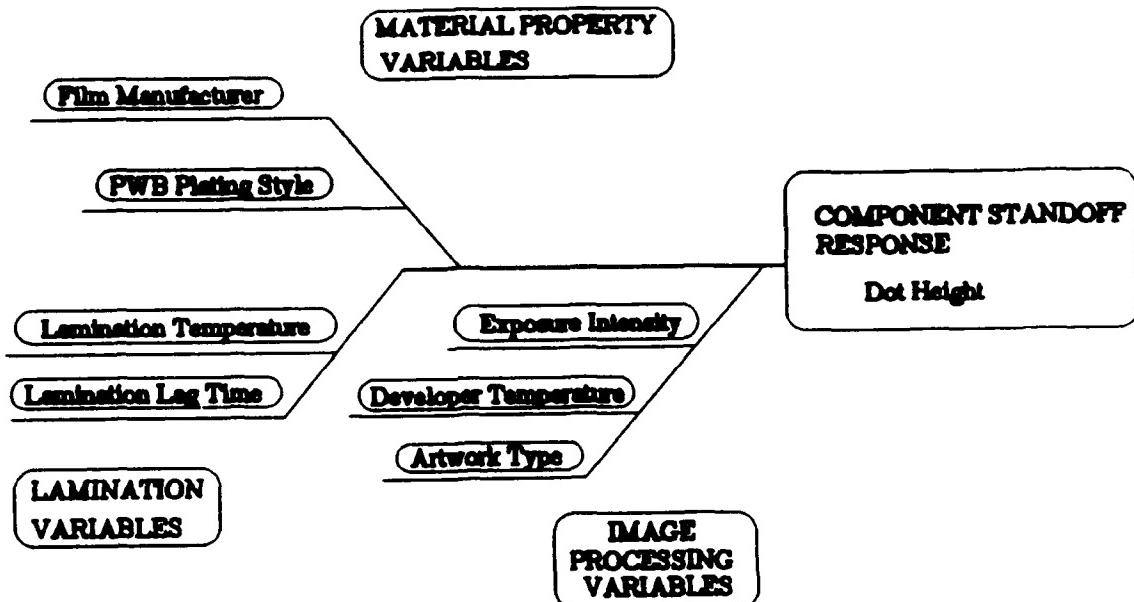
D-3

MATERIAL PROPERTY
VARIABLES

Film Manufacturer

PWB Plating Style

COMPONENT STANDOFF
RESPONSE

Dot Height

Lamination Temperature

Exposure Intensity

Lamination Lag Time

Developer Temperature

Artwork Type

LAMINATION
VARIABLES

IMAGE
PROCESSING
VARIABLES

Figure 1
Component Stand-Off
Cause And Effect Diagram

Table 1

Process Variable Details

Process Variable	Measuring Device/ Precision	Variable Range	Specification
* Dry film developer temperature	Thermocouple indicator +/- 1 deg F	90 to 105 F	Vendor product data
* Dry film exposure intensity	Watt meter +/- 10 watts	2500 to 5000 watts	Vendor product data
* Solder mask vendor	Vendor certification	DuPont and Dynachem	TRW design options
* PWB plating style	Vendor certification	Fused tin-lead and solder dip and hot air leveled	TRW design options
* Lamination temperature	Thermocouple/ +/- 1 deg C	Nominal +/- 5 deg C	Vendor product data
* Lamination lag time to processing	Clock/ +/- 10 mins	Nominal plus 24 hours	Vendor product data
* Style of process film	Visual	diazo and silver halide	General shop practice

* Process variable being studied by this experiment

Table 2

Response Variable Details

Response Variable	Measuring Device/ Precision	Specification Limit	Specification
Stand-off dot height	Light Section microscope. +/- 0.1 mils	nominal. +/- 1.0 mil	Baseline document

Table 3

Response Table With Interaction Effects

Random Order Trial Number	Standard Order Trial Number	Response Observed Values	A		B		C		AB		AC		BC		ABC	
			1	2	1	2	1	2	1	2	1	2	1	2	1	2
	1															
	2															
	3															
	4															
	5															
	6															
	7															
	8															
TOTAL																
NUMBER OF VALUES																
AVERAGE																
EFFECT																

II.   MATERIALS AND SUPPLIES

PWB.-

Qty	PIN	Description
12	786582A	Solder dipped and hot air leveled. no fiducial stretch
	Serial Numbers	A-26, -30, B-60, -65, -67, -75, -78, -82, and four that are tbd
12	786582C	Fused tin-lead, no fiducial stretch
	Serial Numbers	C-106, -131, D-155, -157, -158, -160, -176, -182, and four that are tbd

Artwork.-

PIN	Description
T786582-5/1	0.030-in pad diameter solder mask pattern

Solder Paste.- (None required)

Stencil.- (None required)

Miscellaneous.-

96244 Protective gloves   Jones Associates

Solvents.-

Isopropyl alcohol	TT-I-335
1,1,1-Trichloroethane	MIL-T-81533

III   TOOLS AND EQUIPMENT

Dry film laminator

Dry film exposure unit

Dry film developer

Light section microscope

Thermocouple surface temperature indicator

IV   PROCEDURE

1. Select four 786582A or -B PWBs and serialize as ST3P1A-26, -30, -B-60, and -65; select four 786582C or -D PWBs and serialize as ST3P1C-106, -131, -D-155, and -157. These will represent the two different styles of PWB solder finishes.

2. Select two different dry film solder masks vendors and one dry film solder mask from each. Log and record the identification.

3. The worksheet shown in Table 7 is to be used to run the first experimental matrix for the 'height' response listed in Table 2. Column A is assigned to the 'Dry Film Vendor'; sub-column 1 is for 'DuPont', sub-column 2 is for 'Dynachem'. Column B is assigned to the 'Exposure Intensity'; sub-column 1 is for '2500 watts'; sub-column 2 is for '5000 watts. Column C is assigned to the 'Developer Temperature'; sub-column 1 is for '90 deg F'; sub-column 2 is for the '105 deg F. Column AB is assigned to the 'Lamination Temperature'; sub-column 1 is for 'Nominal Minus 5 Deg C'; sub-column 2 is for 'Nominal Plus 5 Deg C'. Column AC is assigned to the 'Lamination Lag Time' (ie time between lamination and exposure); sub-column 1 is for 'Zero Lag Time'; sub-column 2 is for a '24 Hour Lag Time'. Column BC is assigned to the 'PWB Plating Style'; sub-column 1 is for 'Fused Tin-Lead'; sub-column 2 is for 'Solder Dipped and Hot Air Leveled'. Column ABC is assigned to the 'Process Film Style; sub-column 1 is for 'Diazo film'; sub-column 2 is for 'Silver halide film'.

4. Use the randomized run numbers in the "Random Order Trial Number" column. Sequence the experiment trials using this random number sequence.

5. Clean the serialized PWBs in accordance with the applicators recommendations.

6. Laminate, store, expose, and develop the dry-film solder mask onto the PWB for all the appropriate conditions indicated for the particular experiment being run. Use this processed PWB to collect data for the single response listed in Table 2. Repeat until all eight experiments have been run.

7. The sub-column 1 and 2 range assignments for each process variable column in the Table 7 test matrix were inverted to create the Table 8 worksheet. The run order was rerandomized. Using this new experimental matrix, rerun the experiment. This will result in a reflected set of data to aid in the isolation of interaction effects between the process variables assigned to columns AB, AC, BC, and ABC.

7.a. The serial numbers of these PWBs are: ST3P1B67, -75, -78, -82, and -75 for the solder dipped and hot air leveled PWB styles; and ST3P1D158, -160, -176, and -182 for the fused tin-lead styles.

V.   RESPONSE DATA

A.   Solder Mask Dot Height, 20-Pin LCC Pattern, 10 Mils From Pattern

1. Using a light section microscope, measure the developed solder mask dot heights adjacent to footprint patterns at the locations listed in Table 4.

B.   Solder Mask Dot Height, 20-Pin LCC Pattern, 50 Mils from Pattern

1. Using a light section microscope, measure the developed solder mask dot heights 50 mils from adjacent footprint patterns at the locations listed in Table 4.

C.   Solder Mask Dot Height, 28-Pin LCC Pattern, 20 Mils From Pattern

1. Using a light section microscope, measure the developed solder mask dot heights adjacent to footprint patterns at the locations listed in Table 5.

D.   Solder Mask Dot Height, 28-Pin LCC Pattern, 50 Mils from Pattern

1. Using a light section microscope, measure the developed solder mask dot heights 50 mils from adjacent footprint patterns at the locations listed in Table 5.

E.   Solder Mask Dot Height, 32-Pin LCC Pattern, 20 Mils From Pattern

1. Using a light section microscope, measure the developed solder mask dot heights adjacent to footprint patterns at the locations listed in Table 6.

F.   Solder Mask Dot Height, 32-Pin LCC Pattern, 50 Mils from Pattern

1. Using a light section microscope, measure the developed solder mask dot heights 50 mils from adjacent footprint patterns at the locations listed in Table 6.

Note.- The 132-pin FPD is kept off of the PWB surface by its lead form and does not require solder mask standoffs. Solder mask standoffs are not required under chip components.

VI.   DATA REDUCTION

1. Using the data gathered by this experiment, the response sheets typified by Table 3 will be completed for the responses; and significant interstation process variables will be identified.

2. Additional analyses of the data using analysis of variance (ANOVA) techniques will yield variability, experimental error, and process capability indices data.

3. The analysis and comparison of the reflected matrix with the straight matrices will enable process variable interaction effects to be isolated for those variables assigned to columns AB, AC, BC, and ABC.

Table 4

Standoff Heights
20-Pin LCCs
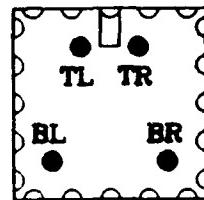
| Component | Standoff Height, mils | | | |
| | separated | | adjacent | |
	TL	TR	BL	BR
U02				
U05				
U19				
U28				
U33				

Table 5

Standoff Heights
28-Pin LCCs
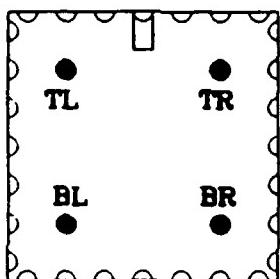
Component	Standoff Height, mils			
	separated		adjacent	
	TL	TR	BL	BR
U22				
U28				
U31				
U35				
U37				

Table 6

Standoff Heights
32-Pin RLCCs
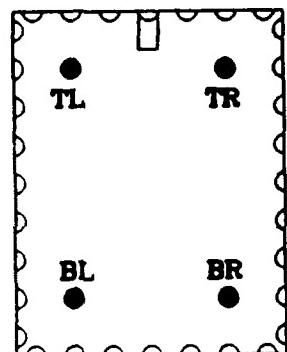
Component	Standoff Height, mils			
	separated		adjacent	
	TL	TR	BL	BR
U07				
U12				
U14				
U34				

Table 7

'Normal' Experimental Run Matrix'

Random Order Trial Number	Standard Order Trial Number	PWB Serial Number	A Dry Film Vendor		B Exposure Intensity watts		C Developer Temperature deg F		AB Dry Film Lam. Temp. C from nom		AC Dry Film Proc Lag Time hours		BC PWB Style		ABC Process Film Style diazo/halide		RESPONSE
			1	2	1	2	1	2	1	2	1	2	1	2	1	2	
4	1	A-28	DuP		2500		90			+5		24		air	diazo		
5	2	C-106	DuP		2500			105		+5	0		fused			halide	
8	3	C-131	DuP			5000	90		-5			24	fused			halide	
3	4	A-30	DuP			5000		105	-5		0			air	diazo		
1	5	B-60		Dyn	2500		90		-5		0			air		halide	
6	6	D-155		Dyn	2500			105	-5			24	fused		diazo		
7	7	D-157		Dyn		5000	90			+5	0		fused		diazo		
2	8	B-65		Dyn		5000		105		+5		24		air		halide	

Table 8

'Reflected' Experimental Run Matrix

Random Order Trial Number	Standard Order Trial Number	PWB Serial Number	A Dry Film Vendor		B Exposure Intensity watts		C Developer Temperature deg F		AB Dry Film Lam. Temp. C from nom		AC Dry Film Proc Lag Time hours		BC PWB Style		ABC Process Film Style diazo/halide		RESPONSE
			1	2	1	2	1	2	1	2	1	2	1	2	1	2	
6	1	D-158		Dyn		5000		105	-5		0		fused			halide	
4	2	B-67		Dyn		5000	90		-5			24		air	diazo		
8	3	B-75		Dyn	2500			105		+5	0			air	diazo		
2	4	D-160		Dyn	2500		90			+5		24	fused			halide	
1	5	D-176	DuP			5000		105		+5		24	fused		diazo		
5	6	B-78	DuP			5000	90			+5	0			air		halide	
7	7	B-82	DuP		2500			105	-5			24		air		halide	
3	8	D-182	DuP		2500		90		-5		0		fused		diazo		

Interoffice Correspondence
TRW Avionics & Surveillance Group

TRW

Subject	**Date**	**From**
Detailed Experimental Plan	19 August 1991	P. CREPEAU
PWA Cleaning (ST32)		
To	**cc**	**Location/Phone**
P. Glaser	D. Cavanaugh	RC4/1073/3182
	P. Finkenbinder	
	J. Murray	
	T. Neillo	

I. INTRODUCTION

This IOC presents the detailed experimental plans and procedures for performing the Subtask 3, Part 2 experimental procedure. This experiment is designed to identify significant inter-workstation process variables that effect several responses for the PWA Cleaning workcell.

The significant process variables were identified in a 'brain storming' session among several manufacturing and process engineers. Figure 1 presents a cause and effect diagram that identifies the process variables and responses for the PWA Cleaning workcell. The encircled process variables are those being evaluated in this experiment. The other process variables are intra-station variables that were previously evaluated and reported.

Ranges (or levels) for the process variables were selected based on tolerances that were expected to be encountered on the factory floor. These ranges, the instruments used to measure the variables, and the reference to the source for the ranges are presented in Table 1. An asterisk identifies those process variables being evaluated by this experiment. Responses to be analyzed for the PWA Cleaning workstation, the instruments used to measure the responses, the specification limits for the responses, and the source for the specification limits are presented in Table 2. This experimental design is a fractional factorial with five process variables. Columns BC and ABC will be used for experimental error measurements. One reflection is required to resolve potential interaction effects. One replicate will also be run. Table 3 presents the form that will be used for each response evaluated by this experimental design.

Figure 1

Component Stand-Off
Cause And Effect Diagram

Table 1

Process Variable Details

	Process Variable	Measuring Device/ Precision	Variable Range	Specification
*	Time since reflow	Timer/ +/- 1 min	0 to 30 mins	Baseline document
*	Reflow temperature	Thermocouple/ +/- 1 deg C	205 to 220 deg C	Baseline document
*	Nitrogen environment	Oxygen analyzer/ +/- 2 percent	70 to 98 percent	Baseline document
*	Component stand-off height	Light section microscope +/- 0.1-mils	4 to 6 mils	Baseline document
*	Solder paste vendor	vendor certification	Metech and Multicore	TRW solder paste evaluation
	Solvent temperature	Thermocouple/ +/- 1 deg C	140 to 160 deg F	Baseline document
	Conveyor speed	Common operator interface/+/- 0.1 fpm	1 to 3 fpm	Baseline document
	Spray zone temperatures	Common operator interface/+/- 1 psi	40 to 50 psi and 170 to 190 psi **	Baseline document

*   Process variable being studied by this experiment
**   40 to 50 psi applies to nominal spray pressures of 45 psi; 170 to 190 psi applies to nominal spray pressures of 180 psi.

Table 2

Response Variable Details

Response Variable	Measuring Device/ Precision	Specification Limit	Specification
Visual cleanliness	Comparison to visual standards/ +/- 1 unit	0 to 4 units	MIL-P-28809
Ionic cleanliness	Ionic contamination tester/+/- 1 ugm NaCl/sq in	0 to 10 ugm NaCl/sq in	MIL-C-28809

Table 3

Response Table With Interaction Effects

Random Order Trial Number	Standard Order Trial Number	Response Observed Values	A		B		C		AB		AC		BC		ABC	
			1	2	1	2	1	2	1	2	1	2	1	2	1	2
	1															
	2															
	3															
	4															
	5															
	6															
	7															
	8															
TOTAL																
NUMBER OF VALUES																
AVERAGE																
EFFECT																

II.   MATERIALS AND SUPPLIES

PWB.-

Qty	PIN	Description
24	786582A	Solder dipped and hot air leveled, no fiducial stretch

Components.-

Qty	PIN	Description
72	70-02	132-pin, DIACON, FPD package
432	PB-C85124	20-pin, LCC
240	PB-44823	28-pin, LCC
192	IRK32F1-200B	32-pin, RLCC
912	M55342K06B-110BR	M55342/6, chip resistor
1008	CDR02BX103-BKURT/BKUS	CDR02, chip capacitor
144	49BCP	CWR06, chip capacitor

Solder Paste.-

Metech RHF63   Metech, Inc
                                     Route 401
                                     Halverson, PA 19520

Multicore SN62RM92A90   Multicore Solders
                                     Cantiague Rock Road
                                     Westbury, NY 11590

Stencil.-

T786582-6/1   6/12 thickness
T786582-6/2   10/14 thickness

Dry Film Solder Mask.-

Vacrel 8100   E.I. DuPont de Nemours
                                     Wilmington, DE

D-21

Solder Mask Artwork.-

T786582-5/1   0.030-in diameter standoff pattern

Miscellaneous.-

Palette knife, plastic   Holbein

Bristle brush

Shamis 99-150 cleaning cloth   Affiliated Manufacturers, Inc.

96244 Protective gloves   Jones Associates

Solvents.-

Isopropyl alcohol   TT-I-335

1,1,1-Trichloroethane   MIL-T-81533

III TOOLS AND EQUIPMENT

General purpose stereoscope, 0.7X to 3X zoom with an American Optical No. 424,
10X, filar eyepiece

Screen Printer No. 24-ASP   MPM Corporation
                                               10 Forge Park
                                               Franklin, MA 02038

Malcom Viscometer   Austin American Technology
                                               12201 Technology Blvd.
                                               Austin, TX 78727

Gelzer Robot   Gelzer Systems
                                               Westerville, OH

In-Line Cleaner, CBL-18   Baron Blakeslee
                                               2001 N. Janice Ave.
                                               Melrose Park, IL 60160

Vapo-Kleen Stencil Cleaner   Universal Electronics, Inc.
Model No. 1110187

Microscan   CyberOptics Corp.
                                               2331 University Ave. S.E.

Minneapolis, MN 55414

IR Reflow Oven, Model SMD 722

Vitronics Corp
40 Forge
Haymarket, NH

Ionic Contamination Tester
Model ICOM 4000

Westek, Inc.
400 Rolyn Place
Arcadia, CA 91006

IV PROCEDURE

A. Eight Run Fractional Factorial Design with Two Reflection and One Replicate Runs.

Note: Select 24 786582A PWBs and serialize as 2001 through -024, and set aside in groups of eight (as defined by Tables 4-6) for the three experiments being run.

1. Initial Reflection

a. Create one worksheet similar to the one shown in Table 3, for each of the responses listed in Table 2, that are to be monitored. Column A is assigned to the 'Solder Joint Reflow Temperature'; sub-column 1 is for '205 deg C'; sub-column 2 is for '220 deg C'. Column B is assigned to the 'Time Since Reflow'; sub-column 1 is for '0 minutes'; sub-column 2 is for '30 minutes'. Column C is assigned to the 'Standoff Height'; sub-column 1 is for '4 mils'; sub-column 2 is for the '6 mils'. Column AB is assigned to the 'Nitrogen Environment'; sub-column 1 is for '79% Nitrogen'; sub-column 2 is for '98% Nitrogen'. Columns AC and BC are reserved for experimental error determinations. Column ABC is assigned to the 'Solder Paste Vendor'; sub-column 1 is for 'Metech'; sub-column 2 is for 'Multicore'.

b. Run the experimental trials for this initial experiment using the random number sequence listed in the "Random Order Trial Number" column of Table 4.

c. Clean the appropriate, serialized PWBs in the in-line solvent cleaner.

d. Set up the 24-ASP stencil printer with an appropriate reference PWB. Keep in mind that different solder paste vendors are being applied to different boards depending on the run number.

e. Set up the component preparation and placement sides of the Gelzer robot.

f. Set up the CBL-18 in-line cleaner with the appropriate 'Digital 1' cleaning process profile.

g. Select the PWB, solder paste, and IR reflow parameters required for the run identified as random number 1 in Table 4.

h. Stencil print the PWB forcing the desired material vendor as required by the test matrix.

i. Place the printed PWB in the Gelzer robot load station and form, trim, tin, and place the selected FPD and all other components using the nominal placement values for all components.

j. Reflow the PWA subassembly in the IR reflow oven under the conditions specified by the Table 20 matrix.

k. Clean the PWA in the CBL-18 in-line cleaner using the machine parameters associated with the PWA serial number listed in Table 4.

l. Repeat steps IV.A.1.c through IV.A.1.k. inclusive, until all 8 experimental runs have been completed for this initial experiment.

2. Reflected Experiment

   a. Using the test parameters and the random order sequence specified by the Table 5 matrix for a reflected run, repeat steps IV.A.1.b - IV.A.1.k.

3. Second Replication Experiment

   a. Using the test parameters and the random order sequence specified by the Table 6 matrix for a second replicated run, repeat steps IV.A.1.b - IV.A.1.k.

V.   RESPONSE DATA

A. Visual Cleanliness Before Ionic Contamination Test

1. Scan each PWA and compare and rank the cleanliness against the visual standards presented in Figure 2. Record the data on a worksheet similar to that presented in Table 4.

B. Ionic Contamination

1. Measure the cleanliness of the PWA using the Westek ICOM 4000 in accordance with MIL-C-28809. Record data on a worksheet similar to that presented in Table 4.

C. Visual Cleanliness After Ionic Contamination Test

1. Remove the U01, U20, U04, U19, U33, U22, U30, U35, U07, U17, and U34 components and visually rank the cleanliness at the component/PWB interface. Use the visual standards presented in Figure 2 for comparison. Record the dat on a worksheet similar to that presented in Table 4.

Figure 2

Visual PWA Cleanliness Standards

0   NO CONTAMINATION VISIBLE REGARDLESS
    OF LIGHT OR MAGNIFICATION (MAX 30X)

1   EDGE OF VISIBILITY, TRANSPARENT
    DRY RESIDUE

2   EASILY VISIBLE, TRANSPARENT DRY
    RESIDUE

3   OPAQUE, WHITE DRY DEPOSIT

4   LIGHT DEPOSIT OF WET FLUX

5   HEAVY DEPOSIT OF WET FLUX

D-26
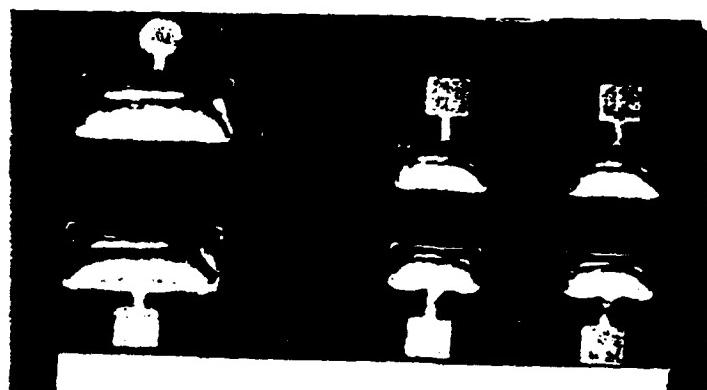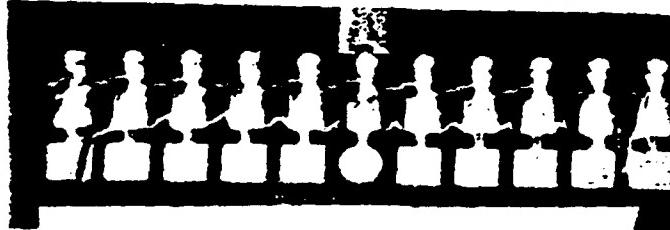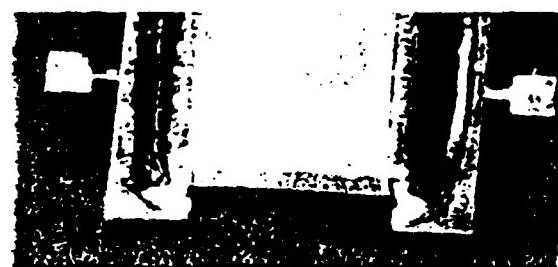
Table 4

Data Collection Table for PWA Cleanliness

PWB SN	CLEANLINESS, VISUAL, 0-5		CLEANLINESS, IONIC
	BEFORE IONIC	AFTER IONIC	Mg NaCl/in2
2001			
2005			
2002			
2006			
2003			
2007			
2004			
2008			
2013			
2009			
2014			
2010			
2015			
2011			
2016			
2012			
2017			
2021			
2018			
2022			
2019			
2023			
2020			
2024			

VI.   DATA REDUCTION

1. Using the data gathered by this experiment, the response sheets typified by Table 3 will be completed for the responses: and significant interstation process variables will be identified.

2. Additional analyses of the data using analysis of variance (ANOVA) techniques will yield variability, experimental error, and process capability indices data.

3. The analysis and comparison of the reflected matrix with the straight matrices will enable process variable interaction effects to be isolated for those variables assigned to columns AB and AC.

Table 5
Replicate No.1 Experiment Recipe

Random Order Trial Number	Standard Order Trial Number	PWB Serial Number	A Solder Joint Reflow Temp. deg C		B Time Since Reflow mins. at amb.		C Standoff Height mils		AB Nitrogen Supply off/on		AC INTERACTION AND ERROR TERMS		BC		ABC Solder Paste Vendor Met/Mult		RESPONSE
			1	2	1	2	1	2	1	2	1	2	1	2	1	2	
03	1	2001	205		0		4			on					Met		
08	2	2005	205		0			6		on						Mult	
02	3	2002	205			30	4		off							Mult	
05	4	2006	205			30		6	off						Met		
12	5	2003		220	0		4		off							Mult	
14	6	2007		220	0			6	off						Met		
16	7	2004		220		30	4			on					Met		
09	8	2008		220		30		6		on						Mult	

Table 6
Reflection No.1 Experiment Recipe

Random Order Trial Number	Standard Order Trial Number	PWB Serial Number	A Solder Joint Reflow Temp. deg C		B Time Since Reflow mins. at amb.		C Standoff Height mils		AB Nitrogen Supply off/on		AC INTERACTION AND ERROR TERMS		BC		ABC Solder Paste Vendor Met/Mult		RESPONSE
			1	2	1	2	1	2	1	2	1	2	1	2	1	2	
07	1	2013		220		30		6	off							Mult	
04	2	2009		220		30	4		off						Met		
03	3	2014		220	0			6		on					Met		
08	4	2010		220	0		4			on						Mult	
05	5	2015	205			30		6		on					Met		
02	6	2011	205			30	4			on						Mult	
06	7	2016	205		0			6	off							Mult	
01	8	2012	205		0		4		off						Met		

Table 7
Replicate No.2 Experiment Recipe

Random Order Trial Number	Standard Order Trial Number	PWB Serial Number	A Solder Joint Reflow Temp. deg C		B Time Since Reflow mins. at amb.		C Standoff Height mils		AB Nitrogen Supply off/on		AC INTERACTION AND ERROR TERMS		BC		ABC Solder Paste Vendor Mot/Mult		RESPONSE
			1	2	1	2	1	2	1	2	1	2	1	2	1	2	
06	1	2017	205		0		4			on					Met		
04	2	2021	205		0			6		on						Mult	
01	3	2018	205			30	4		off							Mult	
07	4	2022	205			30		6	off						Met		
10	5	2019		220	0		4		off							Mult	
11	6	2023		220	0			6	off						Met		
15	7	2020		220		30	4			on					Met		
13	8	2024		220		30		6		on						Mult	

Appendix E

Subtask 4: Fine Pitch Device Lead Forming

SUBTASK 4

FINE PITCH DEVICE LEAD FORMING

I. INTRODUCTION

This document presents the detailed experimental plan and procedures for performing the Sub Task 4 experimental procedure. This experiment is designed to identify significant inter-workstation process variables that affect several responses for the fine pitch device lead forming (FPD) work cell. The significant process variables were identified in a "brainstorming" session among several manufacturing and process engineers. Figure 1 presents a cause and effect diagram that identifies the process variables and responses for the FPD lead forming work cell. The shaded process variables are those being evaluated in this experiment. The unshaded process variables are intrastation variables that were previously evaluated and reported.

Ranges (or levels) for the process variables were selected based on tolerances that were expected to be encountered on the factory floor. These ranges, the instruments used to measure the variables, and the reference to the source for the ranges are presented in Table 1. Double asterisks identify those process variables being evaluated by this experiment. Responses to be analyzed for the FPD lead forming workstation, the instruments used to measure the responses, the specification limits for the responses, and the source for the specification limits are presented in Table 2. This experimental design is a full factorial with three variables. No reflection is required. One replicate will be run, however.

Table 3 presents the form that will be used for each response evaluated by this experimental design. Columns AB, AC, BC, and ABC will be used for experimental error measurements.
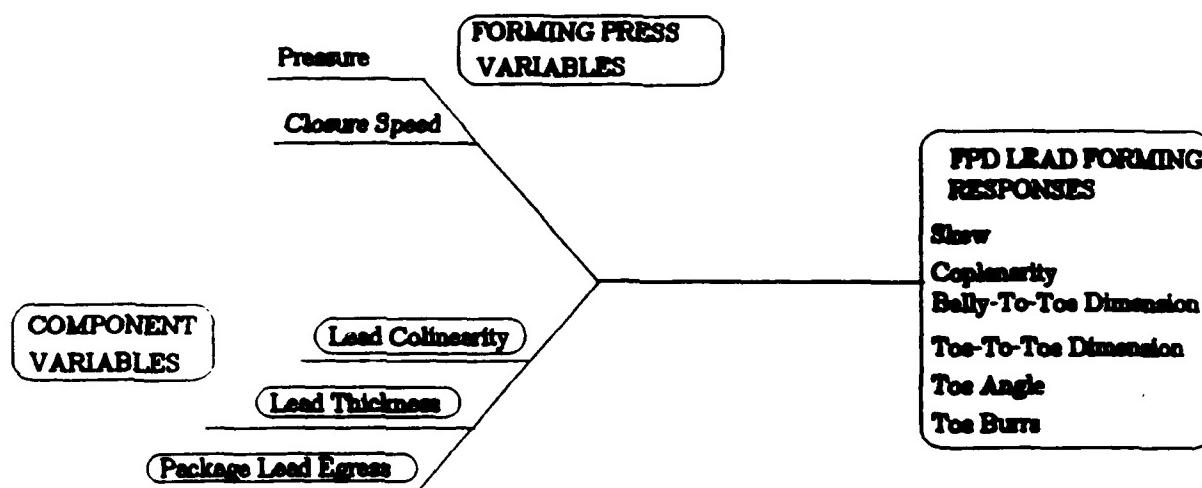
Figure 1.   FPD component forming fishbone chart.

Table 1. Process variable details.

Process Variable	Measuring Device/ Precision	Variable Range	Specification
• Die pressure	Pressure gauge/ +/- 1 psi	80-90 psi 85 psi nominal	TRW EOP
• Die closure rate	Stop watch/ +/- 0.1 sec	0.055-0.057 ft/s 0.056 ft/s nom.	TRW EOP
**Lead colinearity	Coordinatograph or Optical Comparator/ +/- 0.1-mil	+/- 3 mils from orthogonal	Engineering
**Lead thickness	Micrometer/ +/- 0.1-mil	5 to 8 mils	Vendor drawing requirements
**Lead package egress	Microscan/ +/- 0.15-mil	From top of package or side of package	Vendor drawing requirements

Table 2. Response variable details.

Response Variable	Measuring Device/ Precision	Specification Limit	Specification
Skew	Coodinatograph or Optical Comparator/ +/- 0.1-mil	-2 to +2 mils from orthogonal	MIL-STD-2000
Coplanarity	Microscan/ +/- 0.15-mil	4 mil maximum deviance	Engineering
"Belly-to-toe" dimension	Microscan/ +/- 0.15-mil	10 milsl +/- 2 mils	TRW drawing
"Toe-to-toe" dimension	Coordinatograph/ +/- 0.1-mil	Nominal/ +/- 5 mils	TRW drawing
"Toe" angle dimension	Microscan/ +/- 0.15-mil	+/- 15 deg from horizontal	MIL-STD-2000
"Toe" burrs	Microscope with filar/ +/- 0.2 mil	1x lead thickness, max.	MIL-STD-2000

Table 3. Response table with interaction effects.

Serial number/Process Variable Relationship Matrix

Serial Number	Package Style		Lead Thickness		Lead Skew		Run Number	
	Diacon	Kyocera	5 mils	8 mils	-3 mils	+3 mils	Initial	Replicat.
DIA ST4001	XX			XX	XX		3	
DIA ST4002	XX			XX	XX			3
DIA ST4003	XX			XX		XX	4	
DIA ST4004	XX			XX		XX		4
DIA ST4005	XX		XX		XX		1	
DIA ST4006	XX		XX		XX			1
DIA ST4007	XX		XX			XX	2	
DIA ST4008	XX		XX			XX		2
KYO ST4001		XX		XX	XX		7	
KYO ST4002		XX		XX	XX			7
KYO ST4003		XX		XX		XX	8	
KYO ST4004		XX		XX		XX		8
KYO ST4005		XX	XX		XX		5	
KYO ST4006		XX	XX		XX			5
KYO ST4007		XX	XX			XX	6	
KYO ST4008		XX	XX			XX		6

Figure 2

Robotic Workcell, [response name] experimental design matrix

Initial Run

Proposed/Actual Variable States

Random Sequence Number	Run Number	Package Style Prop.	Package Style Act.	Lead Thickness Prop.	Lead Thickness Act.	Lead Skew Prop.	Lead Skew Act.	EXPERIMENTAL ERROR
4	DIA 1 ST4005	DIA		5 mils		-3 mil		
6	DIA 2 ST4007	DIA		5 mils		+3 mil		
1	DIA 3 ST4001	DIA		8 mils		-3 mil		
2	DIA 4 ST4003	DIA		8 mils		+3 mil		
5	KYOC 5 ST4005	KYOC		5 mils		-3 mil		
7	KYOC 6 ST4007	KYOC		5 mils		+3 mil		
3	KYOC 7 ST4001	KYOC		8 mils		-3 mil		
8	KYOC 8 ST4003	KYOC		8 mils		+3 mil		

Figure 3

Robotic Workcell, [response name] experimental design matrix

Replication

Proposed/Actual Variable States

Random Sequence Number	Run Number	Package Style Prop.	Act.	Lead Thickness Prop.	Act.	Lead Skew Prop.	Act.
3	1 DIA ST4006	DIA		5 mils		-3 mil	
8	2 DIA ST4008	DIA		5 mils		+3 mil	
4	3 DIA ST4002	DIA		8 mils		-3 mil	
7	4 DIA ST4004	DIA		8 mils		+3 mil	
6	5 KYOC ST4006	KYOC		5 mils		-3 mil	
2	6 KYOC ST4008	KYOC		5 mils		+3 mil	
5	7 KYOC ST4002	KYOC		8 mils		-3 mil	
1	8 KYOC ST4004	KYOC		8 mils		+3 mil	

EXPERIMENTAL ERROR

Figure 4

II. MATERIALS AND SUPPLIES

PWB - (None required)

Components

Qty	P/N	Description
8	132-pin FPD	Kyocera
8	132-pin FPD	Diacon

Solder paste - (None required)

Stencil - (None required)

Miscellaneous - (None required)

Solvents - (None required)

III. EQUIPMENT, TOOLS AND SUPPORTING DOCUMENTATION

Gelzer integrated preparation and placement workstation (Model #1312).

EOP 10160 (Equipment Operating Procedure for the Gelzer Preparation and Placement Workstation)

General purpose stereo microscope, 0.7x-3x zoom with an American Optical No. 424, 10x-filar eyepiece.

Microscan	CyberOptics Corp. 2331 University Ave SE Minneapolis, MN 55414
Dial Micrometer	Lukins or equivalent
Coplanarity measurement aids	TL001-FORM-1 TL001-FORM-2

IV.   PROCEDURE

A.

NOTE: Refer to the "SERIAL NUMBER/PROCESS VARIABLE RELATIONSHIP MATRIX" (see figure #2) when serializing the FPD packages to determine which variables are forced for each serial number.

1.   Procure eight each of the lidded Kyocera and Diacon 132-pin FPD packages and place a black ink dot on the lid of all 16 packages to indicate pin #1 (see figure #5). Use the same convention for each part type!

2.   Select four Kyocera and four Diacon 132-pin FPD packages, measure their lead thickness, and have them copper, nickel, and gold plated to an additional 3 mils of thickness. Serialize them as KYO ST4001 through -004 and DIA ST4001 through -004.

3.   Select four Kyocera and four Diacon 132-pin packages. Measure their lead thickness. Serialize them as KYO ST4005 through -008 and DIA ST4005 through -008.

4.   Locate the following FPD serial numbers and skew the indicated leads -3 mils, from the orthogonal, at a point located 0.180" from the package body (see figure 7):

FPD SERIAL NUMBER

DIA ST4001	KYO ST4001
DIA ST4002	KYO ST4002
DIA ST4005	KYO ST4005
DIA ST4006	KYO ST4006

Pin 132   Pin 100

Pin 1 indicator ——

Pin 1   Pin 99

KYO
ST4001

Pin 33   Pin 67

NOTE: Pin count runs counterclockwise
around package when viewed
from the package top.

Typical Serial
Number location

Pin 34   Pin 66

FIGURE #5

This edge faces the robot arm ——

4	3	2	1
8	7	6	5
12	11	10	9
16	15	14	13
20	19	18	17

Preparation side elevator feeder
tray #1 pocket locations and
numbering scheme.
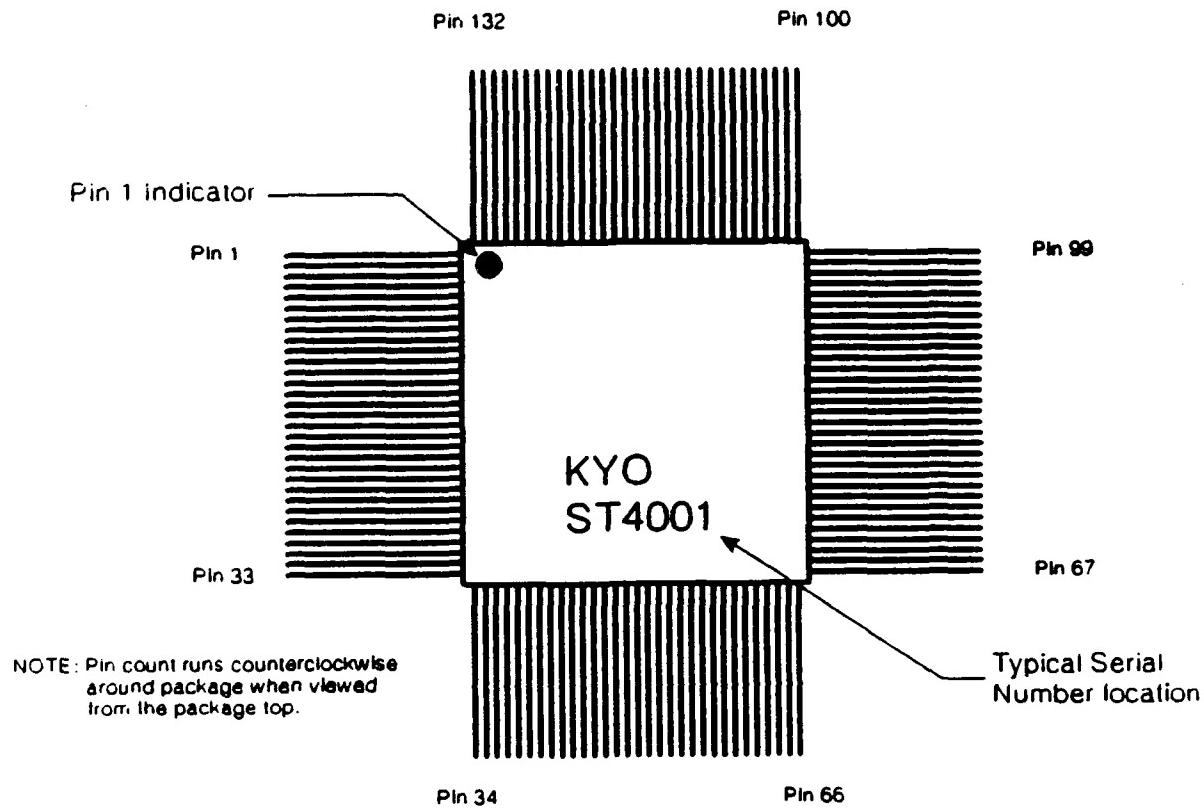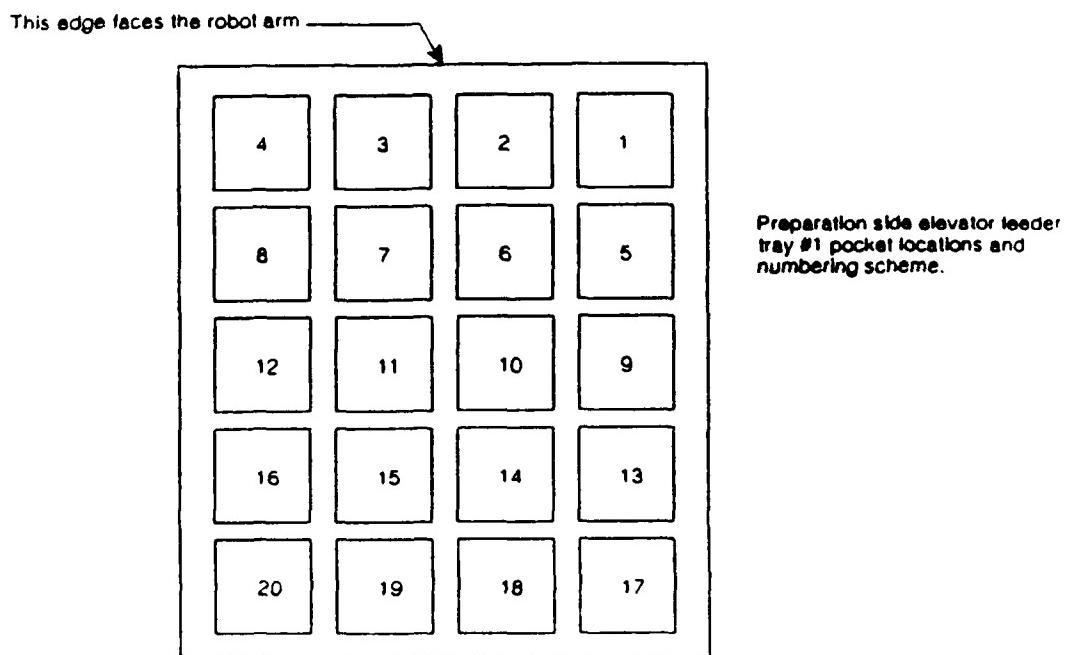
FIGURE #6

E-13

SKEWED LEAD NUMBERS
SIDE 1:   1, 2, 3, 16, 17, 18, 31, 32 and 33

SIDE 2:   34, 35, 36, 49, 50, 51, 64, 65 and 66

SIDE 3:   67, 68, 69, 82, 83, 84, 97, 98 and 99

SIDE 4:   100, 101, 102, 115, 116, 117, 130, 131 and 132

5.   Locate the following FPD serial numbers and skew the indicated leads +3 mils, from the orthogonal, at a point located 0.180" from the package body (see figure 7):

FPD SERIAL NUMBER

DIA ST4003   KYO ST4003
DIA ST4004   KYO ST4004
DIA ST4007   KYO ST4007
DIA ST4008   KYO ST4008

SKEWED LEAD NUMBERS
SIDE 1:   1, 2, 3, 16, 17, 18, 31, 32 and 33

SIDE 2:   34, 35, 36, 49, 50, 51, 64, 65 and 66

SIDE 3:   67, 68, 69, 82, 83, 84, 97, 98 and 99

SIDE 4:   100, 101, 102, 115, 116, 117, 130, 131 and 132

E-14

Lead skew to be forced and measured at this point ─────
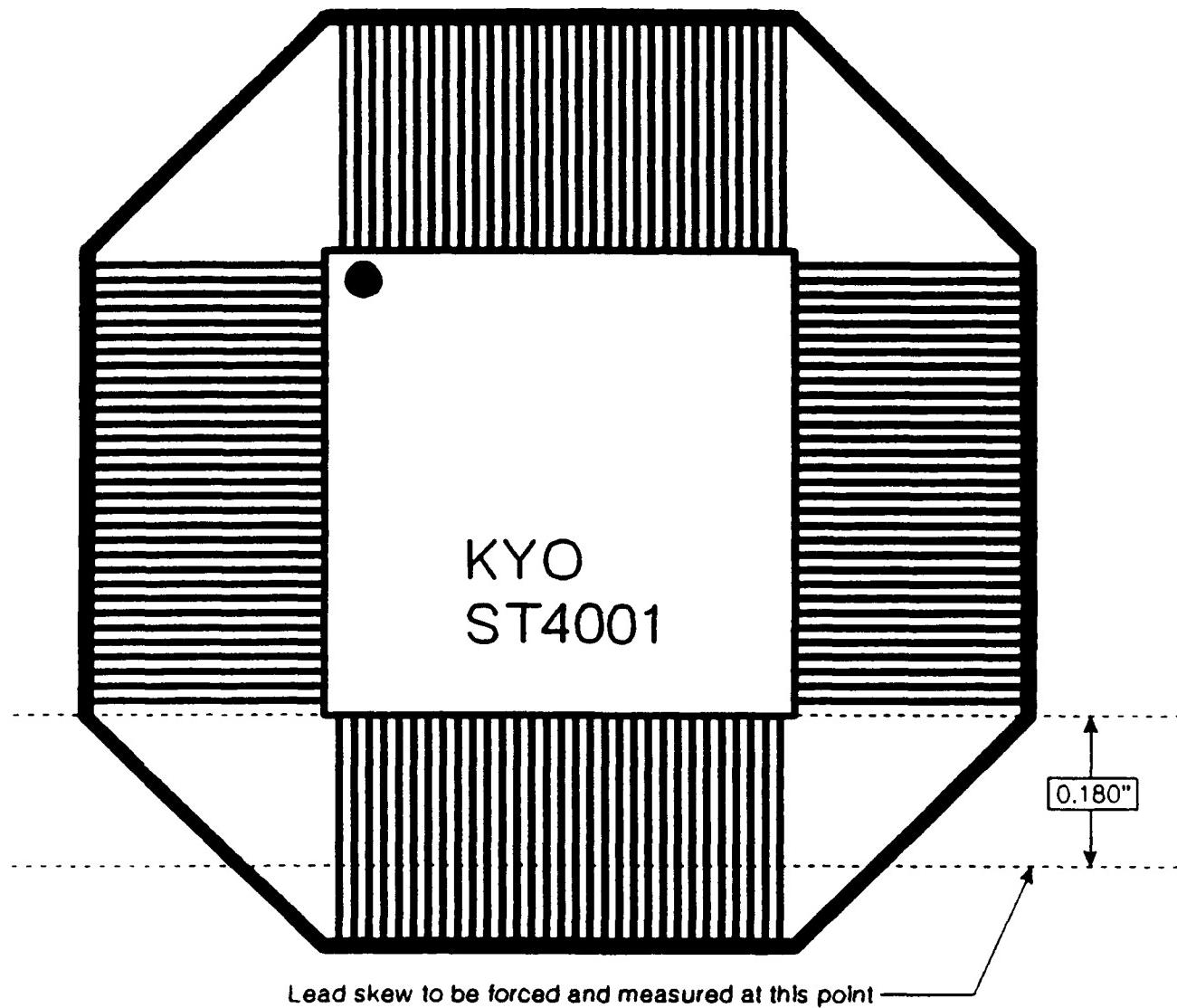
Lead skew shall be forced and measured at a point on each lead that lies 0.180" from the package bdy (see above example). This point on the lead represents the toe of the lead after forming has been performed and shall be typical of all four sides.

FIGURE #7

E-15

6. Measure the coplanarity, before forming, for each of the devices and record this "original condition" data in table 5. Use the Microscan and TL001-FORM-1 to accomplish this.

    NOTE: Use one sheet for each device!

7. Create one worksheet each, similar to the one shown in Table 3, for the initial run and for the replication (see figures #3 & #4). Column A is assigned to the 'Lead Package Egress Style', subcolumn 1 is for 'Diacon', subcolumn 2 is for 'Kyocera'. Column B is assigned to 'Lead Thickness', subcolumn 1 is for 'Nominal', subcolumn 2 is for 'Plus 3 Mils'. Column C is assigned to 'Lead Skew', subcolumn 1 is for a skew of '-3 Mils', subcolumn 2 is for a skew of '+3 Mils'. The remaining columns are for experimental error determinations.

8. Randomize the "Standard Order Trial Number" column and enter the appropriate random number in the "Random Order Trial Number" column. Run the experiment trials using the random number sequence.

9. Set up the component preparation side of the Gelzer robot minus the lead tinning function and load the forming program "FORM.BBF". Do not allow the robot to place any parts in the reject tray as this could affect the lead coplanarity.

10. Place the appropriate 132-pin packages into the preparation elevator tray #1 in accordance with the random sequence order number and starting with pocket #1 (see figure #6). With the feeder tray oriented as shown in figure 6, place the pin #1 indicator of each FPD in the upper left hand corner of the feeder pockets. Form and trim their leads. Collect data for the six responses listed in Table 2. Repeat until all eight experiments have been run.

11.   Take some preliminary measurements to confirm that no other <u>significant</u> variables are affecting the process. Stop and notify the cognizant engineer if there appears to be any undocumented outside influences in the process.

12.   Rerandomize the run order numbers and rerun the experimental matrix. This will result in a replicate set of data to aid in statistical analyses of the experiment.

V.   RESPONSE DATA

A.   Lead Coplanarity

1.   Measure and record the lead coplanarity of the FPD package leads for each of the eight runs at the locations listed in Table 5. Use the Microscan with a precision of 0.15-mil and tool number TL001-FORM-2 to accomplish this.

NOTE: **Due to the delicate nature of the leads and the fact that lead coplanarity can be easily upset, this measurement shall be taken first followed by any others that require the use of the laser profilometer.**

B.   "Toe" Angle

1.   Measure and record the angle of "toe" in the formed lead of the FPD for each of the eight runs at the locations listed in Table 8. Use a Microscan with a precision of 0.15-mil, max. and arrive at the angle through triangulation.

C.   "Belly-to-Toe" Dimensions

1.   Measure and record the dimension from the bottom of the FPD ceramic package to the bottom of the "toe" formed on the lead for each of the eight runs at the locations listed in Table 6. Use a Microscan with a precision of 0.15-mil, max.

D. Lead Skew

1. Measure and record the lead skew or colinearity of the FPD package leads for each of the eight runs at the locations listed in Table 4. Use a coordinatograph to accomplish this. The precision of the measurement shall be 0.1-mil, min.

E. "Toe-to-Toe Dimension

1. Measure and record the minimum and maximum "toe-to-toe" dimension across both sides of the package for each of the eight runs at the locations listed in Table 7. Use a coordinatograph with a precision of 0.1-mil, max.

F. "Toe" Burrs

1. Scan all of the "toes" of the formed leads of the FPD and select the lead with the greatest burr for each of the four sides. Use a filar eyepiece on a microscope with a precision of 0.1-mil to measure that burr and record its lead number and dimension. See Table 9.

VI. DATA REDUCTION

Using the data gathered by this experiment, the response sheets typified by Table 3 will be completed for each response; and significant interstation process variables will be identified.

Additional statistical analyses of the data using analysis of variance (ANOVA) techniques will yield variability, experimental error, and process capability indices data.

Table #4

Lead Skew data collection sheet (One sheet for each device)

Device serial number _____

Side	Lead Numbers (Measure these leads at the lead toe)
1	01 ___ 02 ___ 03 ___ avg ___ 16 ___ 17 ___ 18 ___ avg ___ 31 ___ 32 ___ 33 ___
2	34 ___ 35 ___ 36 ___ avg ___ 49 ___ 50 ___ 51 ___ avg ___ 64 ___ 65 ___ 66 ___
3	67 ___ 68 ___ 69 ___ avg ___ 82 ___ 83 ___ 84 ___ avg ___ 97 ___ 98 ___ 99 ___
4	100 ___ 101 ___ 102 ___ avg ___ 115 ___ 116 ___ 117 ___ avg ___ 130 ___ 131 ___ 132 ___

Table #5

Lead Coplanarity data collection sheet (One sheet for each device)

Device Serial Number _____

Side	Original Condition			Formed Condition		
	Lowest	Highest	Delta	Lowest	Highest	Delta
1						
2						
3						
4						

Table #6

Belly-to-Toe data collection sheet (One sheet for each device) _____

Device serial number _____

Lead Numbers
(Measure these leads at the lead toe)

Side	Lead Numbers		
1	01___ 02___ 03___ avg___	16___ 17___ 18___ avg___	31___ 32___ 33___
2	34___ 35___ 36___ avg___	49___ 50___ 51___ avg___	64___ 65___ 66___
3	67___ 68___ 69___ avg___	82___ 83___ 84___ avg___	97___ 98___ 99___
4	100___ 101___ 102___ avg___	115___ 116___ 117___ avg___	130___ 131___ 132___

Table #7

Side 4
Side 1
Side 2 [A]
KYO
ST4001
Side 2
[B]

Toe-to-Toe data collection sheet
(Use one sheet for all devices)

Serial Number	Dimension A			Dimension B		
	Min.	Max.	Avg.	Min.	Max.	Avg.
DIA ST4001						
DIA ST4002						
DIA ST4003						
DIA ST4004						
DIA ST4005						
DIA ST4006						
DIA ST4007						
DIA ST4008						
KYO ST4001						
KYO ST4002						
KYO ST4003						
KYO ST4004						
KYO ST4005						
KYO ST4006						
KYO ST4007						
KYO ST4008						

Table #8

Toe Angle data collection sheet (One sheet for each device) _____

Device serial number _____

$$\Theta = \tan^{-1}\frac{X}{Y}$$

Lead Numbers
(Measure these leads as shown above)

Side											
1	01__	02__	03__	avg__		16__	17__	18__	avg__		
			31__	32__	33__						
2	34__	35__	36__	avg__		49__	50__	51__	avg__		
			64__	65__	66__						
3	67__	68__	69__	avg__		82__	83__	84__	avg__		
			97__	98__	99__						
4	100__	101__	102__	avg__		115__	116__	117__	avg__		
			130__	131__	132__						

Table #9

Toe Burr data collection sheet (Use one sheet for all devices)
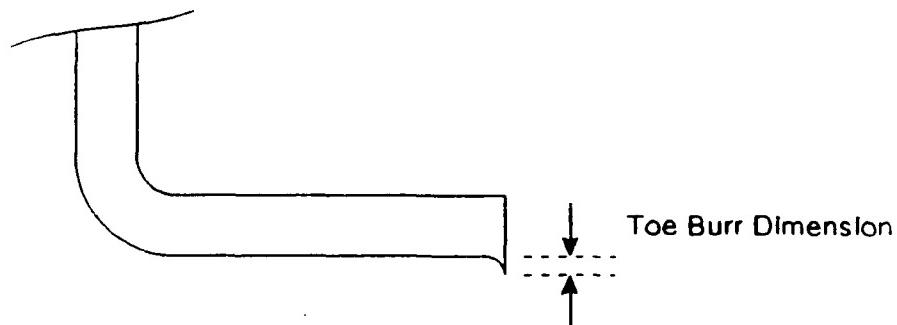
Toe Burr Dimension

| Serial Number | Maximum Burr Dimension | | | | Max Dim of |
	Side 1	Side 2	Side 3	Side 4	All Four Sides
DIA ST4001					
DIA ST4002					
DIA ST4003					
DIA ST4004					
DIA ST4005					
DIA ST4006					
DIA ST4007					
DIA ST4008					
KYO ST4001					
KYO ST4002					
KYO ST4003					
KYO ST4004					
KYO ST4005					
KYO ST4006					
KYO ST4007					
KYO ST4008					

E-24

Diagram A

EMPI TOOL # TL001-FORM

-1

-2

Remove
1.19"
Square

2.00"

0.240

2.00"

2.00"
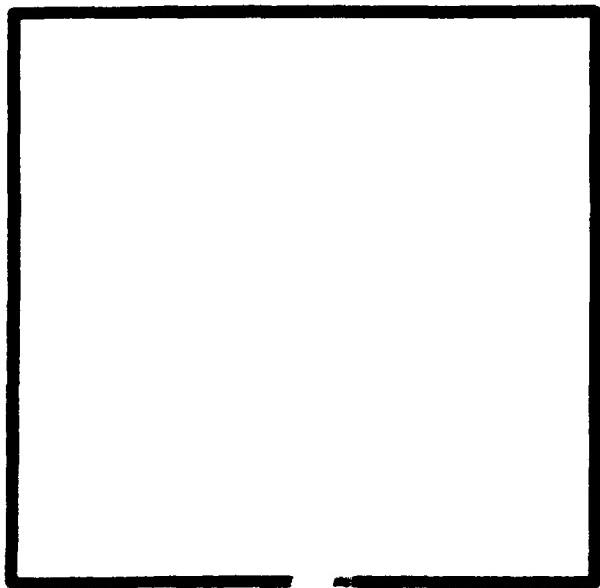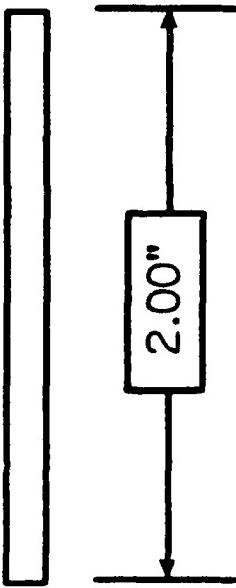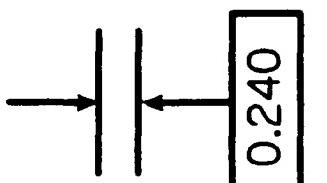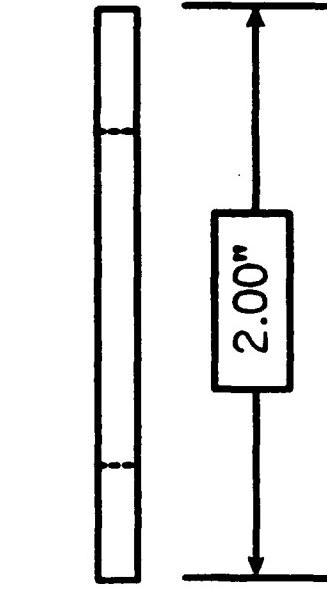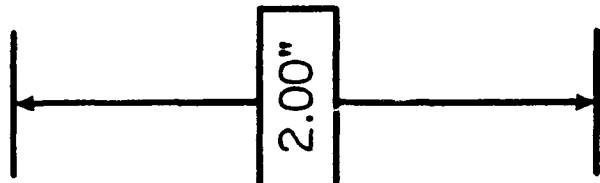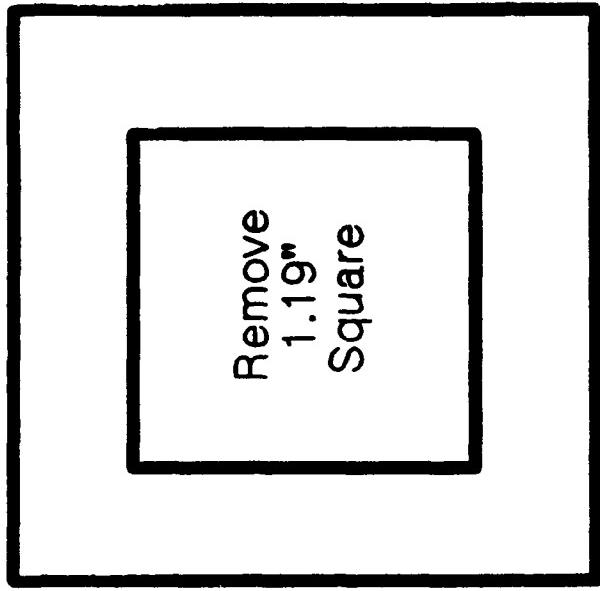
All dimensions in inches +/- 0.01"
Material: Aluminum Alloy, 6061
Flatness to be within 0.0005" across surface

Appendix F

Subtask 5:
Solder Paste Deposition
Component Placement

Interoffice Correspondence
TRW Avionics & Surveillance Group

TRW

This IOC presents the detailed experimental plan and procedures for performing the Sub Task 5, Part 1 experimental procedure. This experiment is designed to identify significant inter-workstation process variables that affect several responses for the solder paste deposition work cell. The significant process variables were identified in a "brainstorming" session among several manufacturing and process engineers. Figure 1 presents a cause and effect diagram that identifies the process variables and responses for the solder paste deposition work cell. The enclosed process variables are those being evaluated in this experiment. The unenclosed process variables are intrastation variables that were previously evaluated and reported.

Ranges (or levels) for the process variables were selected based on tolerances that were expected to be encountered on the factory floor. These ranges, the instruments used to measure the variables, and the reference to the source for the ranges are presented in Table 1. Double asterisks identify those process variables being evaluated by this experiment. Responses to be analyzed for the solder paste deposition workstation, the instruments used to measure the responses, the specification limits for the responses, and the source for the specification limits are presented in Table 2. This experimental design is a full factorial with three variables. No reflection is required. One replicate will be run, however.

Table 3 presents the form that will be used for each response evaluated by this experimental design. Columns AB, AC, BC, and ABC will be used for interaction effects and experimental error measurements.
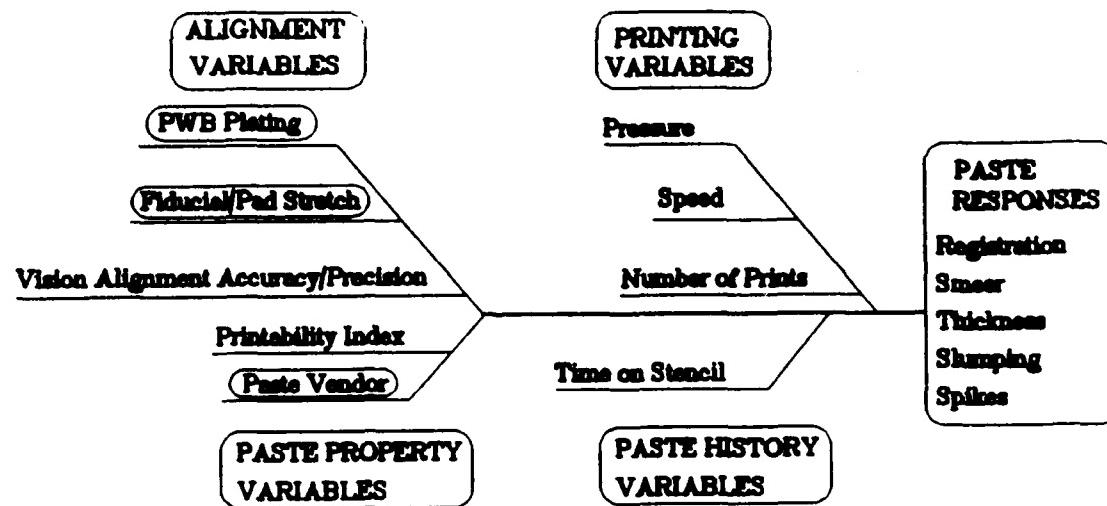
Figure 1. Solder paste deposition cause and effect diagram.

Table 1. Process variable details.

Process Variable	Measuring Device/ Precision	Variable Range	Specification
Squeegee speed	Printer readout/ +/- 0.01-in/min	x.xx - y.yy sec/stroke *	Baseline document
Squeegee pressure	Dial indicator/ +/- 2 psi	x.x - y.y psi *	Baseline document
**Fiducial pad stretch	Coordinatograph +/- 0.1 mil	+3.0 mils from nominal	PWB fabrication drawing
Alignment accuracy/ precision	Microscope with filar/ +/- 0.1 mil	+/- 1.5-mil from nominal	Baseline document
Time on stencil	Timer/ +/- 1-min	0 to 33 hrs	Baseline document
Printability index	Microscope with filar/ +/- 0.1-mil	N/A	Baseline document
Number of prints	Manual count +/- 0	1 to 5	Baseline document
**PWB plating	Inspection/ +/- 0	Reflowed tin-lead and solder dipped/hot air leveled	MEAD Design options
**Solder paste vendor	Inspection/ +/- 0	Metech RF63 and Multicore Sn62-RM92A90	MEAD solder paste study

*   Depends on viscosity of solder paste used.

** Process variables being studied by this experiment.

Table 2. Response variable details.

Response Variable	Measuring Device/ Precision	Specification Limit	Specification
Registration	Microscope with filar/ +/- 0.1-mil	deposit overhang </=25% of pad axis in direction measured	MM para. 2-1
Smear	Microscope with filar/ +/- 0.1-mil	print separation >25% of design spacing	MM para. 2.3
Thickness	Microscan/ +/- 0.1-mil	+/- 20% of stencil thick. at location measured.	MM para. 2.5
Slumping	Microscope with filar/ +/- 0.1-mil	print separation >25% of design spacing.	MM para. 2.7
Spikes	Microscan +/- 0.1 mil	<1 times 't' of stencil thick at location measured.	MM para. 2.7

Table 3. Response table with interaction effects.

II. MATERIALS AND SUPPLIES

PWB

Qty	P/N	Description
6	786582A SN 5, 6, 7, 8, 11, 13	Solder dipped, hot air leveled, no fiducial stretch, normal thickness
7	786582B SN 54, 63, 70, 73, 79, 80, 81	Solder dipped, hot air leveled, max fiducial stretch, normal thickness
7	786582C SN 103, 104, 111, 120, 125, 127, 134	Fused Sn/Pb., no fiducial stretch, normal thickness
6	786582D SN 168, 169, 171, 173, 174, 184	Fused Sn/Pb, maximum fiducial stretch, normal thickness

Solder paste

Metech RHF63	Metech, Inc. Route 401 Halverson, PA 19520
Multicore SN62RM92A90	Multicore Solders Cantiague Rock Road Westbury, NY 11590

Stencil

T-786582-6/1 T-786582-6/2	6/12 mil thickness

Miscellaneous

Palette knife, plastic Bristle brush	Holbein

| Shamis 99-150 cleaning cloth | Affiliated Manufacturers, Inc. |

| 96244 Protective gloves | Jones Associates |

Solvents

| Isopropyl alcohol | TT-I-335 |

| 1,1,1-Trichloroethane | MIL-T-81533 |

III. TOOLS AND EQUIPMENT

General purpose stereo microscope, 0.7x-3x zoom with an American Optical No. 424, 10x-filar eyepiece.

| Screen Printer No. 24-ASP | MPM Corp.
10 Forge Park
Franklin, MA 02038 |

| Malcom Viscometer | Austin America Technology
12201 Technology Blvd
Austin, TX 78727 |

| Vapor degreaser, CBL-18 | Baron-Blakeslee, Inc.
2001 N. Janice Ave.
Melrose Park, IL 60160 |

| Vapo-Kleen Stencil Cleaner
Model No. LP-1824 | Unique Industries, Inc.
Sun Valley, CA |

| Microscan | CyberOptics Corp.
2331 University Ave. SE
Minneapolis, MN 55414 |

IV. PROCEDURE

A.

1. Select one 786582A/B and one 786582C/D PWBs that have fiducial-to-fiducial dimensions that are closest to the drawing nominal. Use these as stencil set-up PWBs. Use a coordinatograph with a precision of +/- 0.1-mil. max., precision to make this determination, and record the numbers.

2. Select two additional 786582A/B and two 786582C/D PWBs that have minimum fiducial-to-fiducial dimensions. Use a coordinatograph with a +/- 0.1-mil. max.. precision to make this determination. and record the numbers.

3. Select two 786582B/A and two 786582D/C PWBs that have maximum fiducial-to-fiducial dimensions. Use a coordinatograph with a +/- 0.1-mil. max.. precision to make this determination. and record the numbers.

4. The worksheet shown in Table 11 is to be used to run the first (or initial) experimental matrix. One worksheet will be used. per response evaluated (Table 2). to record the value of that response for each run in the experiment. Column A is assigned to the 'Solder Past Vendor'. subcolumn 1 is for 'Metech'. subcolumn 2 is for 'Multicore'. Column B is assigned to 'Fiducial Stretch'. subcolumn 1 is for 'Minimum Stretch'. subcolumn 2 is for 'Maximum Stretch'. Column C is assigned to 'PWB Plating Type'. subcolumn 1 is for 'Solder Dipped and Hot Air Leveled'. subcolumn 2 is for 'Tin/Lead Plate and Fused'. The remaining columns are for experimental error determinations.

5. Use the randomized run numbers in the "Random Order Trial Number" column of Table 11. Sequence the experiment trials using this random number sequence.

6. Clean the serialized PWBs in an in-line solvent cleaner or batch vapor degreaser.

7. Set up the ASP-24 stencil printer with the appropriate reference PWBs.

8. Using the combination of solder paste vendor. fiducial stretch PWB. and plating finish required required by Table 11 for a specific run. print two boards in succession and use the second board to collect data for the five responses listed in Table 2. Repeat. until all eight trials have been run.

9. The trial run order in Table 11 was rerandomized and incorporated into the Table 12 worksheet. Using this new experimental matrix. rerun the experiment as was done in paragraphs 1 through 8. above. This will result in a replicated set of data which will enable variability statistics to be determined.

V. RESPONSE DATA

A. Registration

1. Measure the solder paste deposit delta $x(1)$. delta $x(2)$. delta $y(1)$. and delta $y(2)$ misregistration for each of the 16 runs at the locations listed in Table 4. Use a filar eyepiece on a microscope with a precision of at least +/- 0.1-mil.

Table 4.

Solder paste misregistration.

RUN NO. _____   DATE _____

COMPONENT	PAD	△X1	△X2	△Y1	△Y2
U7	29				
U7	28				
U7	28				
U2	04				
U2	05				
U2	06				
U30	25				
U30	24				
U30	23				
U34	11				
U34	12				
U34	13				
U33	14				
U33	15				
U33	16				

△X1

△Y1

△Y2

△X2
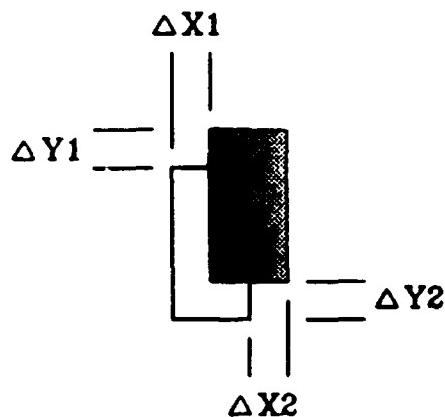
B.   Smears

1.   Visually scan the fine pitch device footprints (U1, 20, and 39) that are parallel to the squeegee blade (x-direction). Measure and record a paste smear condition, on a worksheet similar to that shown by Table 5, that represents 80 percent of the pads and one that represents a worst case condition. Use a microscope with a filar eyepiece with a minimum precision of +/- 0.1 mils.

2.   Repeat B.1. above, for paste deposits that are perpendicular to the squeegee blade (y-direction).

3.   Visually scan the 50-mil pitch LCC device footprints that are parallel to the squeegee blade (x-direction). Measure and record a paste smear condition, on a worksheet similar to that shown by Table 5, that represents 80 percent of the pads and one that represents a worst case condition. Use a microscope with a filar eyepiece with a minimum precision of +/- 0.1 mils.

4.   Repeat B.3. above, for paste deposits that are perpendicular to the squeegee blade (y-direction).

C.   Thickness

1.   Measure and record, on a worksheet similar to that shown by Table 6, the solder paste thickness for each of the 16 runs at the FPD locations listed in Table 6. Use a Microscan with a precision of 0.1-mil max.

2.   Measure and record, on a worksheet similar to that shown by Table 7, the solder paste thickness for each of the 16 runs at the LCC locations listed in Table 7. Use a Microscan with a precision of 0.1-mil max.

3.   Measure and record, on a worksheet similar to that shown by Table 7, the solder paste thickness for each of the 16 runs at the discrete component locations listed in Table 7. Use a Microscan with a precision of 0.1-mil max.

Table 5

Smear on Component Pads

INITIAL RUN. ____
REPLICATE RUN: ____   DATE _____

RUN	X 50-MIL PITCH		Y 50-MIL PITCH		X FINE PITCH		Y FINE PITCH	
	80%	MAX	80%	MAX	80%	MAX	80%	MAX
1								
2								
3								
4								
5								
6								
7								
8								

PARALLEL (X) PADS

PERPENDICULAR (Y) PADS

SQUEEGEE TRAVEL

SQUEEGEE ORIENTATION

F-13

Table 6

Solder paste deposit thickness. FPDs

PWB SN: _____

REF DES	PAD PARALLEL TO SQUEEGEE	PAD PERPENDICULAR TO SQUEEGEE
U01	132	001
	131	002
	130	003
	129	004
	128	005
AVG.		
U20	132	001
	131	002
	130	003
	129	004
	128	005
AVG.		
U39	100	099
	101	098
	102	097
	103	096
	104	095
AVG.		

F-14

Table 7

Solder paste deposit thickness, LCCs

PWB SN: _____

REF DES	PAD PARALLEL TO SQUEEGEE	PAD PERPENDICULAR TO SQUEEGEE
U02	03	04
	02	05
	01	06
AVG.		
U07	30	29
	31	28
	32	27
AVG.		
U38	26	25
	27	24
	28	23
AVG.		
U34	30	29
	31	28
	32	27
AVG.		
U19	19	18
	20	17
	01	16
AVG.		

Table 8

Solder paste deposit thickness. chip components.

PWB SN: _____

CDR02	
C02	01
	02
C04	01
	02
C06	01
	02
AVG.	
C19	01
	02
C20	01
	02
C27	01
	02
AVG.	
C32	01
	02
C33	01
	02
C42	01
	02
AVG.	

CWR06	
C43	01
	02
C46	01
	02
C48	01
	02
AVG.	

M55347	
R01	01
	02
R03	01
	02
R06	01
	02
AVG.	
R34	01
	02
R29	01
	02
R25	01
	02
AVG.	

D. Slumping

1. Visually scan the fine pitch device footprints (U1, 20, and 39) that are parallel to the squeegee blade (x-direction). Measure and record, on a worksheet similar to that shown in Table 9, a paste slump condition that represents 80 percent of the pads and one that represents a worst case condition. Use a microscope with a filar eyepiece with a minimum precision of +/- 0.1 mils.

2. Repeat B.1, above, for paste deposits that are perpendicular to the squeegee blade (y-direction).

3. Visually scan the 50-mil pitch LCC device footprints that are parallel to the squeegee blade (x-direction). Measure and record, on a worksheet similar to that shown in Table 9, a paste slump condition that represents 80 percent of the pads and one that represents a worst case condition. Use a microscope with a filar eyepiece with a minimum precision of +/- 0.1 mils.

4. Repeat B.3, above, for paste deposits that are perpendicular to the squeegee blade (y-direction).

E. Spikes

1. Visually scan the fine pitch device footprints (U1, 20, and 39) that are parallel to the squeegee blade (x-direction). Measure and record, on a worksheet similar to that shown in Table 10, a paste spike condition that represents 80 percent of the pads and one that represents a worst case condition. Use the Microscan with a minimum precision of +/- 0.1 mils.

2. Repeat B.1, above, for paste deposits that are perpendicular to the squeegee blade (y-direction).

3. Visually scan the 50-mil pitch LCC device footprints that are parallel to the squeegee blade (x-direction). Measure and record, on a worksheet similar to that shown in Table 10, a paste spike condition that represents 80 percent of the pads and one that represents a worst case condition. Use the Microscan with a minimum precision of +/- 0.1 mils.

4. Repeat B.3, above, for paste deposits that are perpendicular to the squeegee blade (y-direction).

VI. DATA REDUCTION

Using the data gathered by this experiment, the response sheets typified by Table 3 will be completed for each response; and significant interstation process variables will be identified.

Additional statistical analyses of the data using analysis of variance (ANOVA) techniques will yield variability, experimental error, and process capability indices data.

Table 9

Slump on Component Pads

INITIAL RUN: ____
REPLICATE RUN: ____   DATE _____

RUN	X 50-MIL PITCH		Y 50-MIL PITCH		X FINE PITCH		Y FINE PITCH	
	80%	MAX	80%	MAX	80%	MAX	80%	MAX
1								
2								
3								
4								
5								
6								
7								
8								

PARALLEL (X) PADS

PERPENDICULAR (Y) PADS

SQUEEGEE TRAVEL

SQUEEGEE ORIENTATION

F-19

Table 10

Spikes on Component Pads

INITIAL RUN: ____
REPLICATE RUN: ____   DATE _____

RUN	X 50-MIL PITCH		Y 50-MIL PITCH		X FINE PITCH		Y FINE PITCH	
	80%	MAX	80%	MAX	80%	MAX	80%	MAX
1								
2								
3								
4								
5								
6								
7								
8								

PARALLEL (X) PADS

PERPENDICULAR (Y) PADS

SQUEEGEE TRAVEL

SQUEEGEE ORIENTATION

Table 11

Initial Experimental Run

Random Order Trial Number	Standard Order Trial Number	PWB Serial Number	A Solder Paste Vendor		B Fiducial Stretch mils		C PWB Style		AB INTERACTION AND ERROR TERMS		AC		BC		ABC		RESPONSE
			1	2	1	2	1	2	1	2	1	2	1	2	1	2	
7	1	B-80	Met		0		fused										
1	2	D-173	Met		0			air									
8	3	A-13	Met			+3	fused										
3	4	D-169	Met			+3		air									
2	5	B-63		Multi	0		fused										
6	6	C-13-,		Multi	0			air									
5	7	A-06		Multi		+3	fused										
4	8	C-111		Multi		+3		air									

Table 12

Replicate Experimental Run

Random Order Trial Number	Standard Order Trial Number	PWB Serial Number	A Solder Paste Vendor		B Fiducial Stretch mils		C PWB Style		AB		AC		BC		ABC		RESPONSE
			1	2	1	2	1	2	1	2	1	2	1	2	1	2	
2	1	B-73	Met		0		fused										
6	2	C-120	Met		0			air									
8	3	A-11	Met			+3	fused										
1	4	C-125	Met			+3		air									
7	5	B-81		Multi	0		fused										
3	6	D-174		Multi	0			air									
5	7	A-07		Multi		+3	fused										
4	8	D-171		Multi		+3		air									

INTERACTION AND ERROR TERMS

SUBTASK 5
PART 2

COMPONENT PLACEMENT

I.   INTRODUCTION

This document presents the detailed experimental plan and procedures for performing the Sub Task 5, Part 2 experimental procedure. This experiment is designed to identify significant inter-workstation process variables that affect several responses for the component placement work cell. The significant process variables were identified in a "brainstorming" session among several manufacturing and process engineers. Figure 1 presents a cause and effect diagram that identifies the process variables and responses for the component placement work cell. Those process variables that are being evaluated in this experiment have been encircled. The process variables that are not encircled are intrastation variables that were previously evaluated and reported.

Ranges (or levels) for the process variables were selected based on tolerances that were expected to be encountered on the factory floor. These ranges, the instruments used to measure the variable ranges, and the reference to the source for the ranges are presented in Table 1. Double asterisks identify those process variables being evaluated by this experiment. Responses to be analyzed for the component placement workstation, the instruments used to measure the responses, the specification limits for the responses, and the source for the specification limits are presented in Table 2. The main experimental design is an eight run fractional factorial with five variables. One reflection is required.

Table 3 presents the form that will be used for each response evaluated by this experimental design. Columns BC and ABC will be used for experimental error measurements.

Placement Repeatability

(PWB Plating)

(Component Contrast)

(Fiducial/Pad Stretch)

COMPONENT POSITION
VARIABLES

COMPONENT
PLACEMENT
RESPONSES

Lead/Pad Alignment

Lead Penetration

(PWB Thickness)

Placement Force

(Material Tack/Crust)

Placement Dwell

COMPONENT
DEPTH
VARIABLES
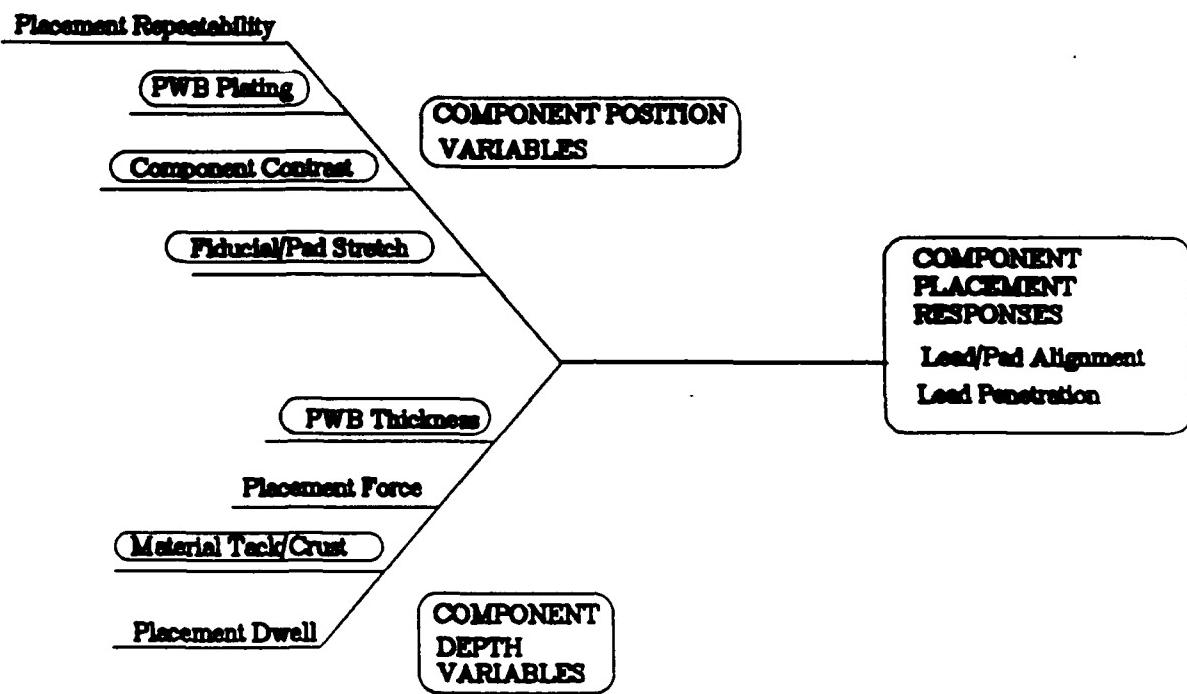
Figure 1. Component placement cause and effect diagram.

Table 1. Process variable details.

Process Variable	Measuring Device/ Precision	Variable Range	Specification
Placement repeatability	Microscope with filar/ +/- 0.2-mil	0 +/- 2mils	Baseline document
**Solder paste open time	Timer/ +/- 1 sec	0.5 to 3 hrs	Assembly staging time
**PWB plating	Procurement Specification/ +/- 0	Fused tin/lead and solder dipped/ hot air leveled	MEAD design options
**Tinned lead aging	Steam ager/ +/- 1 minute	0 to 8 hours (0 to 1 year)	Engineering judgment
**Fiducial pad stretch	Coordinatograph or optical comparator/ +/- 0.1-mil	+ 3 mils from nominal	PWB fabrication drawing
Placement force	Robot/ +/- 1 gram	5gm to 50gm per lead	TRW placement study
**PWB thickness	Dial micrometer/ +/- 0.1-mil	58-68 mils nom to nom +10 mils	PWB fabrication drawing

**Process variables being studied by this experiment.

Table 2. Response variable details.

Response Variable	Measuring Device/ Precision	Specification Limit	Specification
Lead/pad alignment	Microscope with filar +/- 0.2-mil		MIL-STD-2000 (Except where noted)
A. Chip component overhang		10% of termination width, max	
B. Lap		5-mil, max	
C. Lead and toe overhang		25% of lead width, max or 20 mils, max; whichever is greater	
D. Heel clearance		100% of lead width	
E. Leadless chip carrier overhang		25% of castellation width, max	MM 3.3
Lead penetration into solder paste	Microscan/ 0.15-mil	No air gap to 3 mils	MEAD placement study

Table 3. Response table with interaction effects.

Serial Number / Process variable Relationship Matrix

SERIAL NUMBER	MFRS SERIAL NUMBER	LEAD AGING		PWB TYPE		SOLDER PASTE AIR EXPOSURE TIME		PWB THICKNESS		FIDUCIAL STRETCH		RUN NUMBER
		0	1 YEAR	SOLDER DIPPED H.A.L	Sn/Pb FUSED	0.5 HOUR	3 HOUR	THIN	THICK	NOMINAL	STRETCH	
582A S/N 1001	A001	xx		xx		xx			xx		xx	1
582A S/N 1002	A006		xx	xx			xx	xx			xx	6
582A S/N 1003	A008		xx	xx		xx			xx		xx	4R
582B S/N 1101	B054	xx		xx			xx		xx	xx		2
582B S/N 1102	B061		xx	xx		xx		xx		xx		5
582B S/N 1103	B062		xx	xx			xx		xx	xx		3R
582B S/N 1104	B070	xx		xx		xx		xx		xx		8R
582B S/N 1105	B076	xx		xx			xx	xx			xx	7R
582C S/N 1201	C101	xx			xx	xx		xx			xx	3
582C S/N 1202	C103		xx		xx		xx	xx			xx	8
582C S/N 1203	C104	xx			xx	xx			xx	xx		4
582C S/N 1204	C127		xx		xx		xx	xx		xx		7
582C S/N 1205	C133		xx		xx	xx			xx	xx		1R
582D S/N 1301	165	xx			xx	xx		xx		xx		6R
582D S/N 1302	D178		xx		xx		xx		xx		xx	2R
582D S/N 1303	D184	xx			xx		xx		xx		xx	5R

Table 4

Robotic Workcell, [response name] experimental design matrix

Random Sequence Number	Initial Run — Run Number	Proposed/Actual Variable States — Lead Aging Prop.	Act.	PWB Type Prop.	Act.	Solder Paste Air Exposure Time Prop.	Act.	PWB Thickness Prop.	Act.	Fiducial Stretch Prop.	Act.	Experimental Error	Forced Sub-response
8	582A 1 1001	0		Solder Dipped Hot Air Leveled		0.5hr		Thick		Str			
1	582B 2 1101	0		Solder Dipped Hot Air Leveled		3.0hr		Thick		Nom			
3	582C 3 1201	0		Sn/Pb Fused		0.5hr		Thin		Str			
2	582C 4 1203	0		Sn/Pb Fused		3.0hr		Thin		Nom			
5	582B 5 1102	1 yr		Solder Dipped Hot Air Leveled		0.5hr		Thin		Nom			
4	582A 6 1002	1 yr		Solder Dipped Hot Air Leveled		3.0hr		Thin		Str			
7	582C 7 1204	1 yr		Sn/Pb Fused		0.5hr		Thick		Nom			
6	582C 8 1202	1 yr		Sn/Pb Fused		3.0hr		Thick		Str			

Table 5

F-29

Robotic Workcell, [response name] experimental design matrix

Random Sequence Number	Run Number	Lead Aging		PWB Type		Solder Paste Air Exposure Time		PWB Thickness		Fiducial Stretch		Experimental Error	Forced Sub-response
		Prop.	Act.	Prop.	Act.	Prop.	Act.	Prop.	Act.	Prop.	Act.		
2	582C 1 1205	1 yr		Sn/Pb Fused		3.0hr		Thin		Nom			
6	582D 2 1302	1 yr		Sn/Pb Fused		0.5hr		Thin		Str			
8	582B 3 1103	1 yr		Solder Dipped Hot Air Leveled		3.0hr		Thick		Nom			
5	582A 4 1003	1 yr		Solder Dipped Hot Air Leveled		0.5hr		Thick		Str			
3	582D 5 1303	0		Sn/Pb Fused		3.0hr		Thick		Str			
7	582D 6 1301	0		Sn/Pb Fused		0.5hr		Thick		Nom			
4	582B 7 1105	0		Solder Dipped Hot Air Leveled		3.0hr		Thin		Str			
1	582B 8 1104	0		Solder Dipped Hot Air Leveled		0.5hr		Thin		Nom			

Reflection

Proposed/Actual Variable States

Experimental Error

Table 6

II.   MATERIALS AND SUPPLIES

<u>PWB</u> (One each of the following)

<u>P/N</u>	<u>Manufacturers S/N</u>	<u>Description</u>
786582A	A-001	Solder dipped hot air leveled, stretched fiducial
786582A	A-006	Solder dipped hot air leveled, stretched fiducial
786582A	A-008	Solder dipped hot air leveled, stretched fiducial
786582B	B-054	Solder dipped hot air leveled, nominal fiducial
786582B	B-061	Solder dipped hot air leveled, nominal fiducial
786582B	B-062	Solder dipped hot air leveled, nominal fiducial
786582B	B-070	Solder dipped hot air leveled, nominal fiducial
786582B	B-076	Solder dipped hot air leveled, stretched fiducial
786582C	C-101	Fused tin/lead, stretched fiducial
786582C	C-103	Fused tin/lead, stretched fiducial
786582C	C-104	Fused tin/lead, nominal fiducial
786582C	C-127	Fused tin/lead, nominal fiducial
786582C	C-133	Fused tin/lead, nominal fiducial
786582D	D-165	Fused tin/lead, nominal fiducial
786582D	D-178	Fused tin/lead, stretched fiducial
786582D	D-184	Fused tin/lead, stretched fiducial

Component

Qty		P/N	Description
96		49BCP	CWR06 tantalum chip capacitor
16		70-02	Diacon 132-pin FPD
160		CDR02BX103BKURT	CDR02 chip capacitor
16		IMKX3F1-4546AA	NTK 132-pin FPD
64		IRK32F1-200B	32-pin RLCC
112		M55342K06B-110BR	M55342/6 chip resistor
16		PB-F86259	Kyocera 132-pin FPD
80		PB-C85124	20-pin LCC
64		PB-44823	28-pin LCC

Solder paste

Metech RHF63

Metech, Inc.
Route 401
Halverson, PA 19520

Stencil

T-786582-6/1   6/12 thickness
T-786582-6/2

Miscellaneous

Palette knife, plasticHolbein
Shamis, 99-150 cleaning cloth   Affiliated manufacturers
Bristle brush
Protective gloves   Jones Associates

<u>Solvents</u>

Isopropyl alcohol   TT-I-335
1,1,1-trichlorethane   MIL-T-81533

III.   TOOLS AND EQUIPMENT

General purpose stereo microscope, 0.7x-3x zoom with an American Optical No. 424, 10x-filar eyepiece and a Trimos vertical digital readout.

Vision Assisted Stencil Printer Model No. 24-ASP	MPM Corp. 10 Forge Park Franklin, MA 02035
Malcom Viscometer	Austin American Technology 12201 Technology Blvd Austin, TX 78727
Batch & In-Line Vapor Degreaser Models MLR-120 & CBL-18 (as noted or equiv.)	Baron-Blakeslee, Inc. 2001 N. Janice Ave. Melrose Park, IL 60160
Stencil Cleaner (as noted or equiv.)	Tooltronics, Inc. 710 Ivy Street Glendale, CA 91204
Laser Profilometer Microscan	CyberOptics Corp. 2331 University Ave., SE Minneapolis, MN 55414
Robotic Preparation and Placement Workcell Model 1312	Gelzer Systems 425 Enterprise Drive Westerville, OH 43081
Steam Aging Cabinet (as noted or equiv.)	MountainGate Engineering 1510 Dell Ave. Campbell, CA 95008

IV. ROBOTIC PLACEMENT PROCESS OVERVIEW

During the course of a printed wiring assembly build cycle, several functions are performed by the workcell in a logical sequence. The following are brief explanations of those functions, offered in the same order in which the workcell performs them.

A. BOARD BUILD FILE DOWNLOAD

1. Board build files are comprised of the PWB CAD data which specifies component and fiducial locations, component part numbers and component orientation. Also included in the file are certain PWB attributes such as PWB thickness and presentation orientation. The required board build file is, on demand, loaded to active memory from either the main storage disk (hard drive) or the VAX host.

2. The loaded file is then reviewed in the controller to verify that component feeders have been designated and that component description files are in place for all part numbers existing in the file.

B. BOARD BUILD SEQUENCE

1. The PWB is loaded onto the workholder, the cycle is initiated and the PWB is shuttled into the workcell so that it may be accessed by the robotic arm.

2. A downward looking camera locates the global fiducials and generates the pattern offset for the PWB.

3. The required nozzle is obtained by the robotic arm and the build sequence begins as delineated in the board build file.

4. Each component is picked up, in the designated sequence, vision inspected (see description below) for orientation and geometry and then placed on its respective pad pattern with offset compensation applied.

5.   This process continues until all parts have been placed at which time the completed assembly is shuttled back out of the workcell where it is once again accessable to the operator.

C.   VISION INSPECTION (SEE FIGURE 2)

NOTE: The vision information given here pertains only to those components being studied in the experiment.

1.   CHIP COMPONENTS

Due to the size of most chip components, the vision algorithm is designed to look at the entire part outline and determine orientation by differentiating between the major and minor axes of the component geometry. This algorithm does not separate the metalization from the non-conductive component body. Figure 2 shows the basic outline of a chip component as seen by the vision system. The component outline is generated by presenting the component to an upward looking camera, illuminating the underside via a fluorescent ring illuminator and viewing the pattern reflected from the component body.

2.   LEADLESS COMPONENTS

The vision algorithm utilized for the inspection of two-leaded capacitors and ceramic leadless chip carriers (CLCC's) is designed to differentiate the lead metalization from the non-conductive component body and produce an image of the leads alone. Examples of the different component images may be seen in figure 2. The lead outlines are counted and compared with the component description file for part verification. The centroid of each lead outline is then derived and compared to each other so that the centroid of the component can be calculated along with its orientation (offset). The component outline is generated by

The following diagrams are designed to depict, approximately, what will appear in the vision monitor during a component placement centering inspection. The images here do not necessarily represent the exact image as is seen by the observer. Shown below are representations of the vision images for the components used in this experiment. They are offered for reference only!

Chip Component

2 Leaded Tantalum Capacitor

20 Pin CLCC
(Ceramic Leadless Chip Carrier)

28 Pin CLCC
(Ceramic Leadless Chip Carrier)

28 Pin CLCC
(Ceramic Leadless Chip Carrier)

132 Pin CQFP
(Ceramic Quad Flatpack)
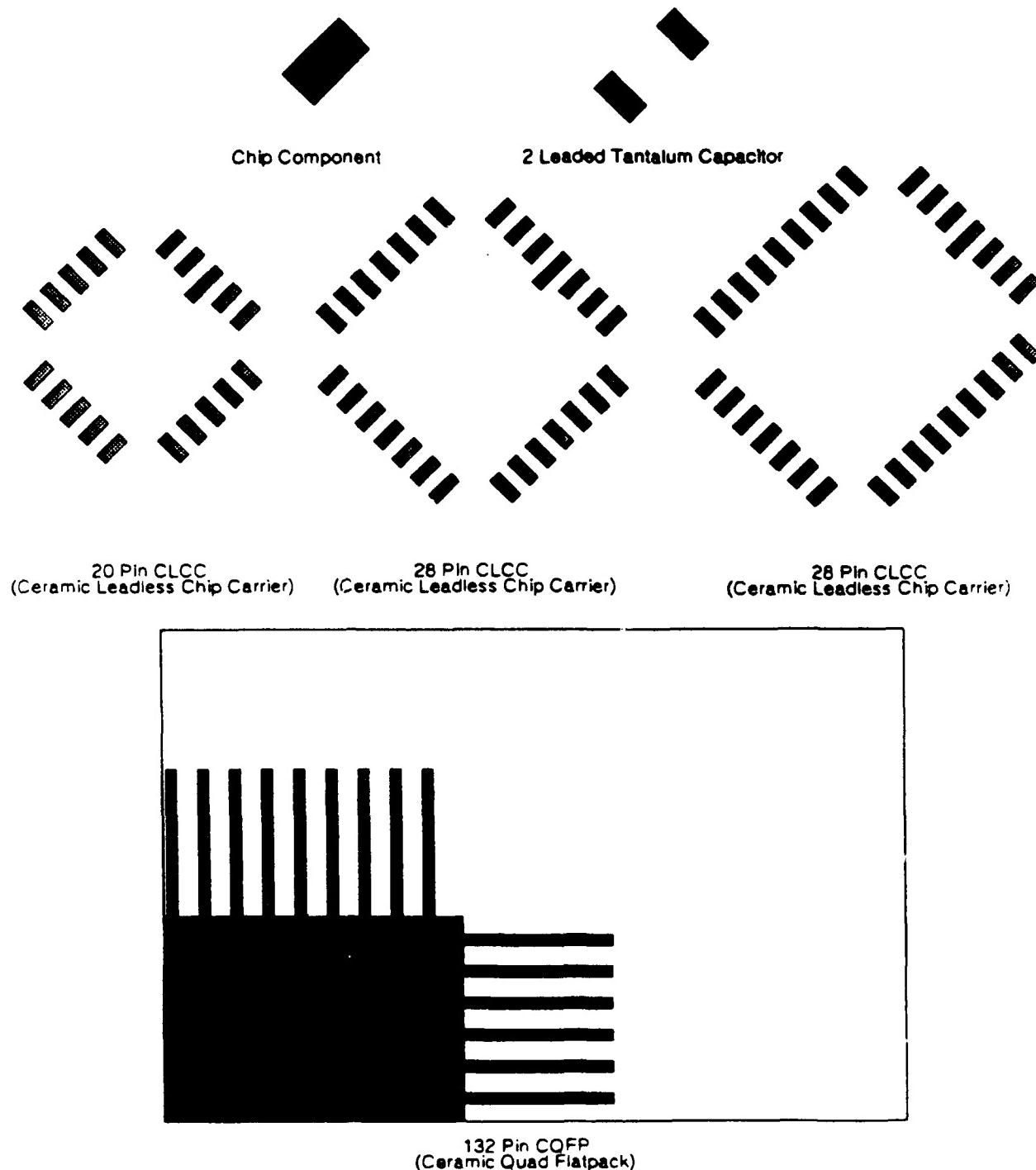
Figure 2
F-36

presenting the component to an upward looking camera, illuminating the underside via a fluorescent ring illuminator and viewing the pattern reflected from the component lead metalization.

3.   LEADED COMPONENTS

The vision algorithm for the 132-pin ceramic quad flatpacks (CQFP's) is designed to create a silhouette of the components leads. Figure 2 shows an example of this silhouette image as seen by the vision system. The silhouette is created by backlighting the component via an ultra-violet illuminator and a luminescent surface situated directly behind the component and attached to nozzle. Six leads to either side of a component body corner are viewed and utilized to locate that corner with respect to the lead outline. This process is repeated for the remaining three corners (the component is rotated three times) and the derived corner locations are used to derive the centroid of the lead outline and its orientaion (offset).

V.   PROCEDURE

NOTES: Since the vision algorithm for the chip components views the component body and not the leads and since this image is unaffected by the age of the component, the M55342K06B-110BR chip resistor and the CDR02BX103BKURT chip capacitor will not be steam aged for the purposes of this experiment.

The maximum placement force capability for the placement workcell currently violates the TRW factory requirements of 5 - 50 grams per lead for any device with an I/O of greater than 80 leads.

The following table delineates the placement force per lead for the components used in this experiment. These values were derived directly from actual measured values for each respective component.

Description	Force (gr/lead)
Chip resistor	**50**
Chip capacitor	**50**
Tantalum capacitor	**50**
20-pin CLCC	**20**
28-pin CLCC	**14**
32-pin RCLCC	**13**
132-pin CQFP	**3**

A. Serialize the experimental PWB's as follows:

1. Locate the required PWB's in accordance with section II (Materials and Supplies), sub-heading PWB.

2. Clean the PWB's in a vapor degreaser.

3. Orient each PWB and white *ink stamp* the experimental serial number in accordance with figure 3 and the following table. Column 1 shows the manufacturers serial numbers and column 2 shows the experimental serial numbers.

TABLE 7

Manufacturers S/N	Experimental S/N
A001	582A S/N 1001
A006	582A S/N 1002
A008	582A S/N 1003
B054	582B S/N 1101
B061	582B S/N 1102
B062	582B S/N 1103
B070	582B S/N 1104
B076	582B S/N 1105

EMPI PWB COMPONENT LOCATIONS
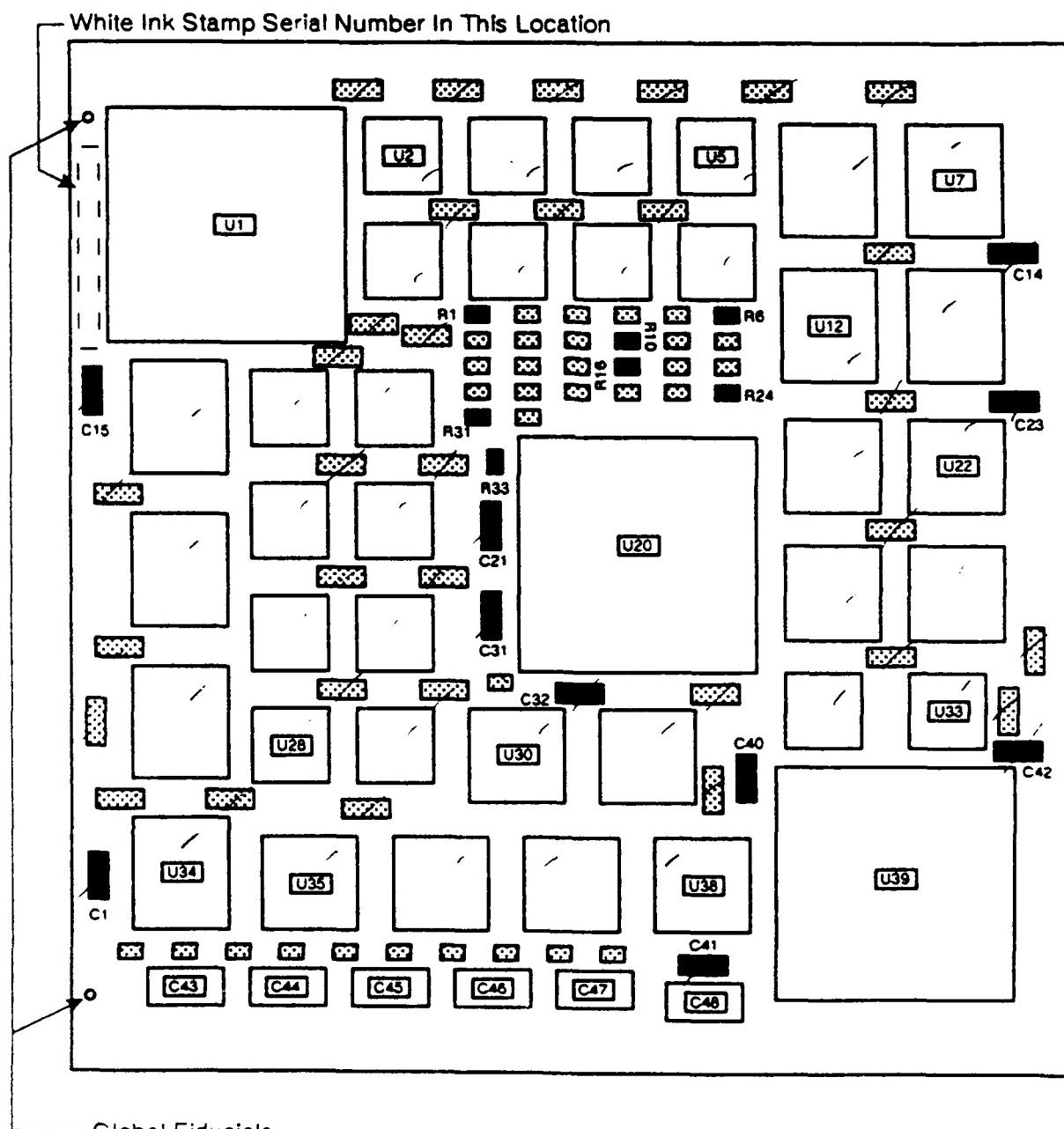
White Ink Stamp Serial Number In This Location

Global Fiducials

PWB Measurement Orientation

Figure 3

C101	582C S/N 1201
C103	582C S/N 1202
C104	582C S/N 1203
C127	582C S/N 1204
C133	582C S/N 1205
D165	582D S/N 1301
D178	582D S/N 1302
D184	582D S/N 1303

B. Serialize the components as follows:

1. Locate the required components in accordance with section II (Materials and Supplies), sub-heading component.

2. Clean the components in a vapor degreaser.

3. Orient each component and black ink stamp the experimental serial number in accordance with figure 4 and the following table. Column 1 shows the component part numbers and column 2 shows the experimental serial numbers.

TABLE 8

Component P/N	Experimental S/N's
PB-C85124	C20-01 THRU C20-80
PB-44823	C28-01 THRU C20-64
IRK32F1-200B	C32-01 THRU C32-64
70-02	DIA F132-01 THRU DIA F132-16
IMKX3F1-4546AA	NTK F132-01 THRU NTK F132-16
PB-F86259	KYO F132-01 THRU KYO F132-16

Componenet Serialization Reference

Pin 1 indicator—

Pin 1 indicator—

Pin 1 indicator—

C20 01

PB-C85124

C28 01

PB-44823

C32 01

IRK32F1-200B

Pin 132   Pin 100

Pin 1 Indicator ———

Pin 1   Pin 99

KYO F132-01

Pin 33   Pin 67

NOTE: Pin count runs counterclockwise around package when viewed from the package top.

Typical Serial Number location

Pin 34   Pin 66
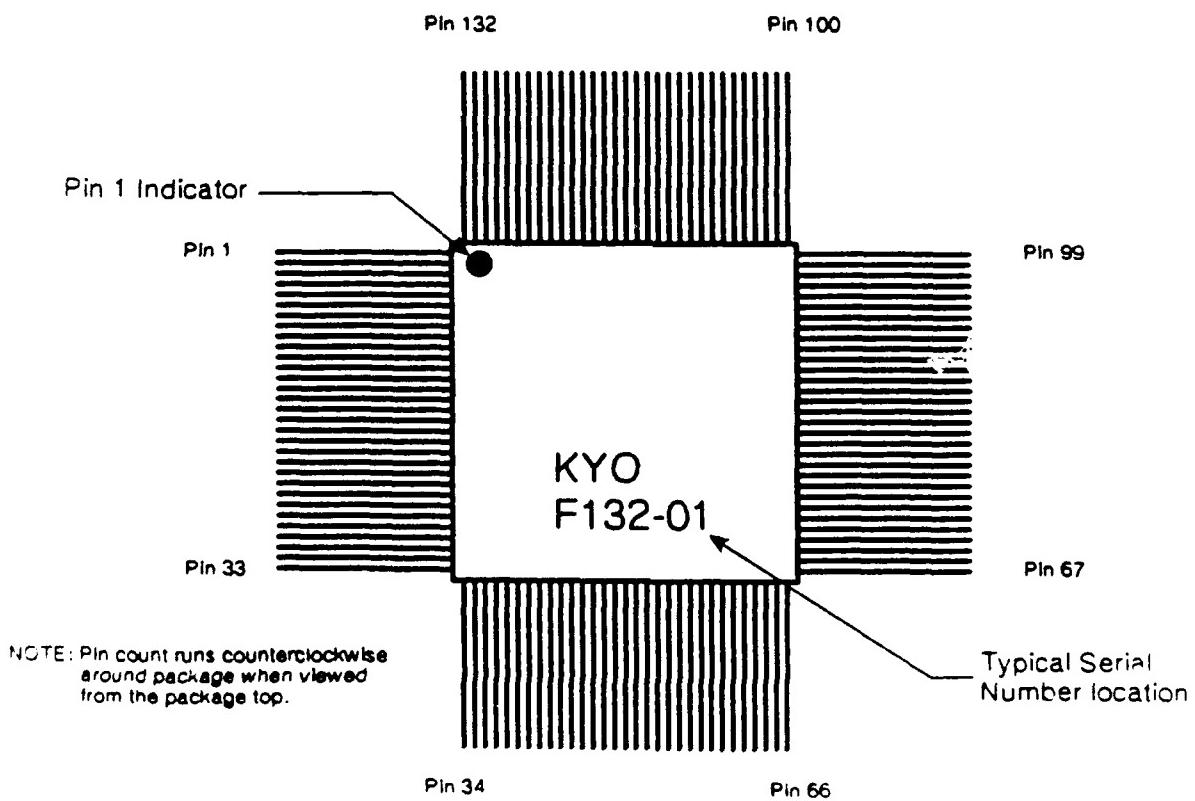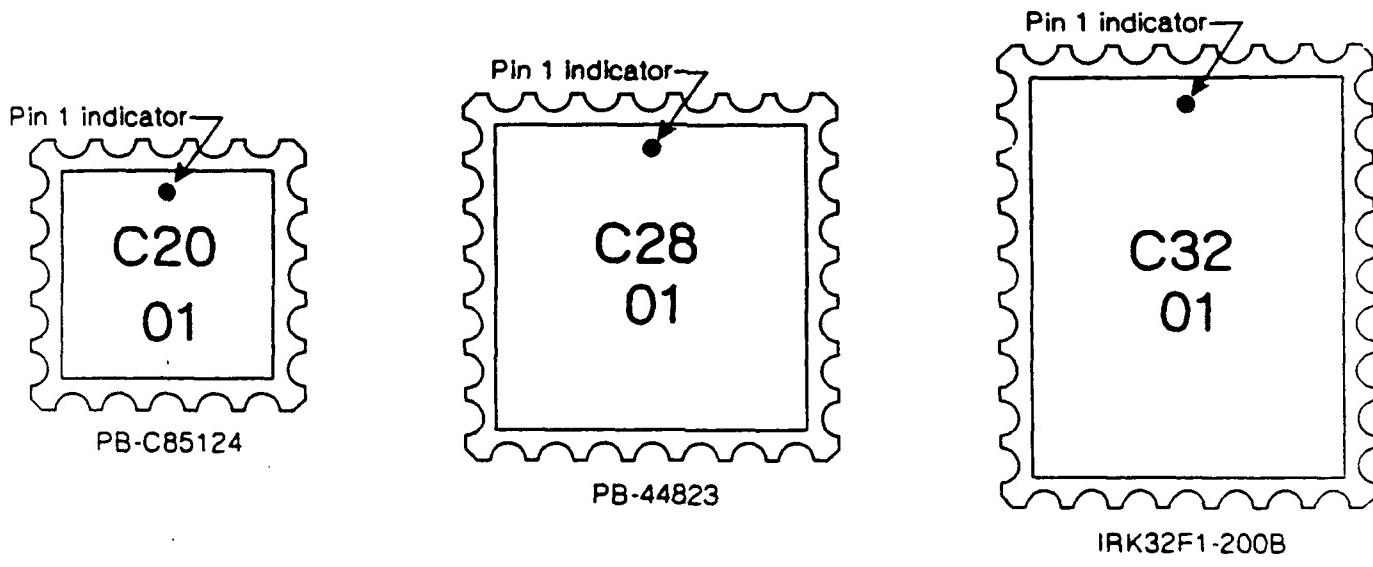
FIGURE 4

C. EXPERIMENTAL DESIGN MATRICES

1. Initial Run

   Create one "experimental design matrix" identical to the one shown in Table 5, for each of the two responses listed in Table 2 that are to be monitored. Column A is assigned to 'Tinned Lead Aging', subcolumn 1 is for 'Zero Aging', subcolumn 2 is for '1 year Aging'. Column B is

   assigned to 'PWB Type'; subcolumn 1 is for ' Solder Dipped and Hot Air Leveled', subcolumn 2 is for 'Tin/Lead Plate and Fused'. Column C is assigned to 'Solder Paste Open Time', subcolumn 1 is for '0.5-Hour Open Time' subcolumn 2 is for '3-Hour Open Time'. Column AB is assigned to 'PWB Thickness', subcolumn 1 is for 'Thin', subcolumn is for 'Thick', Column AC is assigned to 'Fiducial Stretch', subcolumn 1 is for 'Minimum Stretch', subcolumn 2 is for 'Maximum Stretch'. The remaining columns are for experimental error. Utilize the "random sequence number" order that is listed in table 5 for experimental run sequencing.

2. Reflection

   Create one "experimental design matrix" identical to the one shown in Table 6, for each of the two responses listed in Table 2 that are to be monitored. Column A is assigned to 'Tinned Lead Aging', subcolumn 1 is for 'Zero Aging', subcolumn 2 is for '1 year Aging'. Column B is assigned tc 'PWB Type'; subcolumn 1 is for ' Solder Dipped and Hot Air Leveled', subcolumn 2 is for 'Tin/Lead Plate and Fused'. Column C is assigned to 'Solder Paste Open Time', subcolumn 1 is for '0.5-Hour Open Time' subcolumn 2 is for '3-Hour Open Time'. Column AB is assigned to 'PWB Thickness', subcolumn 1 is for 'Thin', subcolumn is for 'Thick', Column AC is assigned to 'Fiducial Stretch', subcolumn 1 is for 'Minimum Stretch', subcolumn 2 is for 'Maximum Stretch'.

The remaining columns are for experimental error. Utilize the "random sequence number" order that is listed in table 6 for experimental run sequencing.

D. Steam age the experimental components as follows:

1. Locate 48 of the CWR06 Tantalum chip capacitors (P/N 49BCP) and put them aside for exposure to the steam aging process. Remove these components from their reel if necessary.

2. Locate the following components by the given serial numbers for exposure to the steam aging process:

Component P/N	Serial Numbers
PB-C85124	C20-41 THRU C20-80
PB-44823	C28-33 THRU C20-64
IRK32F1-200B	C32-33 THRU C32-64
70-02	DIA F132-09 THRU DIA F132-16
IMKX3F1-4546AA	NTK F132-09 THRU NTK F132-16
PB-F86259	KYO F132-09 THRU KYO F132-16

3. Clean all of the selected components in a vapor degreaser just prior to their exposure to the steam aging process.

4. Keeping the component part types seperate, subject the components to eight (8) hours worth of the steam aging process.

5. Bag and tag these components as "AGED" and store them for later use.

E.   Collect initial height measurements on the components as follows:

1.   Locate the following components:

PB-C85124   all
PB-44823   all
IRK32F1-200B   all
70-02   all
IMKX3F1-4546AA   all
PB-F86259   all

2.   Measure the component height at the designated pins in accordance with tables 9, 10 and 11 for the following components:

PB-C85124   all
PB-44823   all
IRK32F1-200B   all

3.   Measure the lead thickness at the designated pins in accordance with table 12 for the following components:

70-02   all
IMKX3F1-4546AA   all
PB-F86259   all

4.   Record all measurements for these components in their respective tables.

F.   Collect and record the PWB thicknesses. Using a micrometer that has a resolution of at least 0.1 mils, measure the PWB's once in each corner and once in the center for a total of five (5) points. Average these points and record this figure below. Measure the PWB's on the bare substrate material and not on the metalization.

F-44

Manufacturers S/N	Experimental S/N	PWB Thickness
A001	582A S/N 1001	_____
A006	582A S/N 1002	_____
A008	582A S/N 1003	_____
B054	582B S/N 1101	_____
B061	582B S/N 1102	_____
B062	582B S/N 1103	_____
B070	582B S/N 1104	_____
B076	582B S/N 1105	_____
C101	582C S/N 1201	_____
C103	582C S/N 1202	_____
C104	582C S/N 1203	_____
C127	582C S/N 1204	_____
C133	582C S/N 1205	_____
D165	582D S/N 1301	_____
D178	582D S/N 1302	_____
D184	582D S/N 1303	_____

G.   Clean the serialized PWBs in the in-line vapor degreaser.

H.   Clean all of the components in a vapor degreaser.

NOTE: **Gloves or finger cots must be worn for all PWB and component handling from this step on and continued until all components have been placed.**

I.   Form the 48 FPD's as follows:

NOTE: **As explained earlier, the FPD leads are inspected by backlighting the leads to create a silhouette of the leads. Since the view is not of the lead itself but of its outline, the presence of solder on the lead does not affect the robots ability to accurately place the device.**

Table 9

20 Pin LCC Initial Height Measurements

(Measure the Component Height at the Designated Pins)

Component S/N	Pin 3	Pin 8	Pin 13	Pin 18	avg.
C20 - 01					
C20 - 02					
C20 - 03					
C20 - 04					
C20 - 05					
C20 - 06					
C20 - 07					
C20 - 08					
C20 - 09					
C20 - 10					
C20 - 11					
C20 - 12					
C20 - 13					
C20 - 14					
C20 - 15					
C20 - 16					
C20 - 17					
C20 - 18					
C20 - 19					
C20 - 20					
C20 - 21					
C20 - 22					
C20 - 23					
C20 - 24					
C20 - 25					
C20 - 26					
C20 - 27					
C20 - 28					
C20 - 29					
C20 - 30					
C20 - 31					
C20 - 32					
C20 - 33					
C20 - 34					
C20 - 35					
C20 - 36					
C20 - 37					
C20 - 38					
C20 - 39					

Table 9 (continued)

Component S/N	Pin 3	Pin 8	Pin 13	Pin 18	avg.
C20 - 40					
C20 - 41					
C20 - 42					
C20 - 43					
C20 - 44					
C20 - 45					
C20 - 46					
C20 - 47					
C20 - 48					
C20 - 49					
C20 - 50					
C20 - 51					
C20 - 52					
C20 - 53					
C20 - 54					
C20 - 55					
C20 - 56					
C20 - 57					
C20 - 58					
C20 - 59					
C20 - 60					
C20 - 61					
C20 - 62					
C20 - 63					
C20 - 64					
C20 - 65					
C20 - 66					
C20 - 67					
C20 - 68					
C20 - 69					
C20 - 70					
C20 - 71					
C20 - 72					
C20 - 73					
C20 - 74					
C20 - 75					
C20 - 76					
C20 - 77					
C20 - 78					
C20 - 79					
C20 - 80					

Table 10

28 Pin LCC Initial Height Measurements

(Measure the Component Height at the Designated Pins)

Component S/N	Pin 4	Pin 11	Pin 18	Pin 25	avg.
C28 - 01					
C28 - 02					
C28 - 03					
C28 - 04					
C28 - 05					
C28 - 06					
C28 - 07					
C28 - 08					
C28 - 09					
C28 - 10					
C28 - 11					
C28 - 12					
C28 - 13					
C28 - 14					
C28 - 15					
C28 - 16					
C28 - 17					
C28 - 18					
C28 - 19					
C28 - 20					
C28 - 21					
C28 - 22					
C28 - 23					
C28 - 24					
C28 - 25					
C28 - 26					
C28 - 27					
C28 - 28					
C28 - 29					
C28 - 30					
C28 - 31					
C28 - 32					
C28 - 33					
C28 - 34					
C28 - 35					
C28 - 36					
C28 - 37					
C28 - 38					
C28 - 39					

Table 10 (continued)

Component S/N	Pin 4	Pin 11	Pin 18	Pin 25	avg.
C28 - 40					
C28 - 41					
C28 - 42					
C28 - 43					
C28 - 44					
C28 - 45					
C28 - 46					
C28 - 47					
C28 - 48					
C28 - 49					
C28 - 50					
C28 - 51					
C28 - 52					
C28 - 53					
C28 - 54					
C28 - 55					
C28 - 56					
C28 - 57					
C28 - 58					
C28 - 59					
C28 - 60					
C28 - 61					
C28 - 62					
C28 - 63					
C28 - 64					

Table 11

32 Pin LCC Initial Height Measurements

(Measure the Component Height at the Designated Pins)

Component S/N	Pin 4	Pin 13	Pin 20	Pin 29	avg.
C32 - 01					
C32 - 02					
C32 - 03					
C32 - 04					
C32 - 05					
C32 - 06					
C32 - 07					
C32 - 08					
C32 - 09					
C32 - 10					
C32 - 11					
C32 - 12					
C32 - 13					
C32 - 14					
C32 - 15					
C32 - 16					
C32 - 17					
C32 - 18					
C32 - 19					
C32 - 20					
C32 - 21					
C32 - 22					
C32 - 23					
C32 - 24					
C32 - 25					
C32 - 26					
C32 - 27					
C32 - 28					
C32 - 29					
C32 - 30					
C32 - 31					
C32 - 32					
C32 - 33					
C32 - 34					
C32 - 35					
C32 - 36					
C32 - 37					
C32 - 38					
C32 - 39					

Table 11 (continued)

Component S/N	Pin 4	Pin 13	Pin 20	Pin 29	avg.
C32 - 40					
C32 - 41					
C32 - 42					
C32 - 43					
C32 - 44					
C32 - 45					
C32 - 46					
C32 - 47					
C32 - 48					
C32 - 49					
C32 - 50					
C32 - 51					
C32 - 52					
C32 - 53					
C32 - 54					
C32 - 55					
C32 - 56					
C32 - 57					
C32 - 58					
C32 - 59					
C32 - 60					
C32 - 61					
C32 - 62					
C32 - 63					
C32 - 64					

Table 12

132 Pin FPD Initial Lead Thickness Measurements

(Measure the Lead Thickness at the Designated Pins)

Component S/N	Pin 1	Pin 2	Pin 3	avg	Pin 34	Pin 35	Pin 36	avg	Pin 67	Pin 68	Pin 69	avg	Pin 100	Pin 101	Pin 102	avg
Dia F132-01																
Dia F132-02																
Dia F132-03																
Dia F132-04																
Dia F132-05																
Dia F132-06																
Dia F132-07																
Dia F132-08																
Dia F132-09																
Dia F132-10																
Dia F132-11																
Dia F132-12																
Dia F132-13																
Dia F132-14																
Dia F132-15																
Dia F132-16																
NTK F132-01																
NTK F132-02																
NTK F132-03																
NTK F132-04																
NTK F132-05																
NTK F132-06																
NTK F132-07																
NTK F132-08																
NTK F132-09																
NTK F132-10																
NTK F132-11																

Table 12 (continued)

132 Pin FPD Initial Lead Thickness Measurements

(Measure the Lead Thickness at the Designated Pins)

Component S/N	Pin 1	Pin 2	Pin 3	avg	Pin 34	Pin 35	Pin 36	avg	Pin 67	Pin 68	Pin 69	avg	Pin 100	Pin 101	Pin 102	avg
NTK F132-12																
NTK F132-13																
NTK F132-14																
NTK F132-15																
NTK F132-16																
Kyo F132-01																
Kyo F132-02																
Kyo F132-03																
Kyo F132-04																
Kyo F132-05																
Kyo F132-06																
Kyo F132-07																
Kyo F132-08																
Kyo F132-09																
Kyo F132-10																
Kyo F132-11																
Kyo F132-12																
Kyo F132-13																
Kyo F132-14																
Kyo F132-15																
Kyo F132-16																

The presence of solder on the lead, however, will hinder the ability to accurately measure the lead offset by increasing the lead thickness by an undetermined amount. Measurement of the leads after forming, which would be required if the leads were tinned, is not desired nor recommended due to the possibility of accidental lead skew from the extra handling. Any accidental lead skew induced in these devices can and, in most cases, will affect the robots ability to accurate place these devices which could, and probably will, lead to skewed results. For these given reasons, the fine pitch devices will not be tinned for the purposes of this experiment. They will, however, be steam aged.

1. Energize the Gelzer Model 1312 robotic workcell as per EOP10160.

2. Reset the L132 compont description file at the preparation side controller to trim, form, and inspect only.

3. Adjust the preparation side trim die to accept the Diacon 132-pin FPD (# 70-02).

4. At the placement side controller, load the program named "FORM.BBF."

5. Load the 8 as received Diacon packages into tray #1 of the preparation side parts elevator with pin #1 of each component in the upper right hand corner of its respective pocket (see figure 5).

6. Start the board build cycle and form these eight (8) devices.

NOTE: The "FORM.BBF" file only forms eight (8) devices at one time.

7. Load the 8 aged Diacon packages into tray #1 of the preparation side parts elevator with pin #1 of each component in the upper right hand corner of its respective pocket (see figure 5).

Preparation side evevator feeder tray orientation and pocket locations

This edge faces the robot arm

|			
4	3	2	1
8	7	6	5
12	11	10	9
16	15	14	13
20	19	18	17
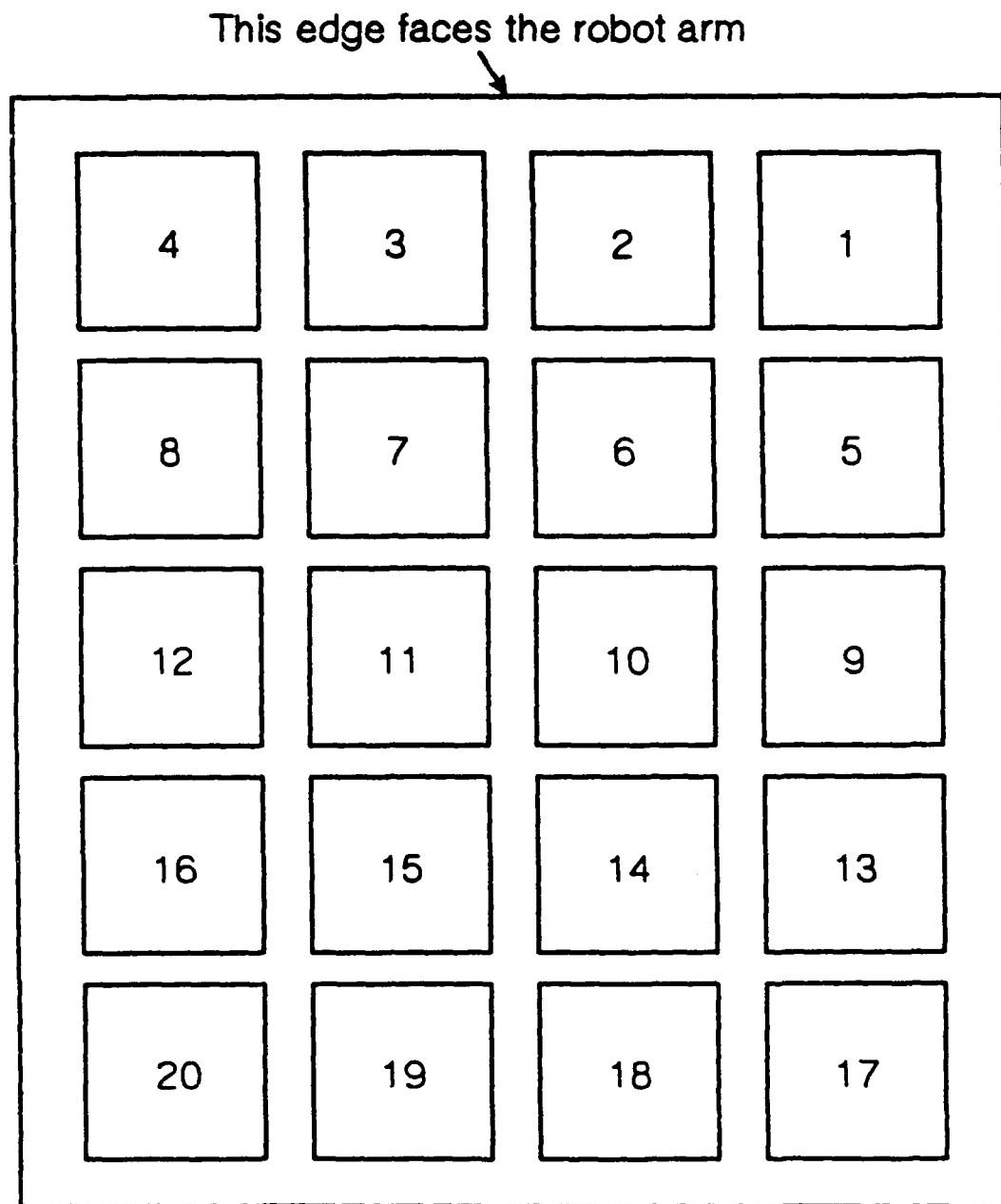
Figure 5

8. Reset the feeder and then re-initiate the board build file to form the last eight (8) devices.

9. Carefully load these formed devices in elevator tray #10 of the workcell placement side part elevator with the "as received" devices situated in the two (2) left feeder columns and the "aged" devices situated in the two (2) right feeder columns. Pin #1 of each device shall be located in the upper left hand corner of its respective pocket (see figure 5).

NOTES: Place these devices in the elevator tray in accordance with the "random sequence number" as delineated in the matrices shown in figures 5 and 6.

Extreme care must be taken to not contact the leads of these formed devices as this could possibly induce an offset in the component placement that would skew the experimental results!

10. Adjust the preparation side trim die to accept the NTK 132-pin FPD (# IMKX3F1-4546AA).

11. At the placement side controller, load the program named "FORM.BBF."

12. Load the 8 as received NTK packages into tray #1 of the preparation side parts elevator with pin #1 of each component in the upper right hand corner of its respective pocket (see figure 5).

13. Reset the feeder and start the board build cycle to form these eight (8) devices.

NOTE: The "FORM.BBF" file only forms eight (8) devices at one time.

14. Load the 8 aged NTK packages into tray #1 of the preparation side parts elevator with pin #1 of each component in the upper right hand corner of its respective pocket (see figure 5).

15. Reset the feeder and then re-initiate the board build file to form the last eight (8) devices.

16. Carefully load these formed devices in elevator tray #11 of the workcell placement side part elevator with the "as received" devices situated in the two (2) left feeder columns and the "aged" devices situated in the two (2) right feeder columns. Pin #1 of each device shall be located in the upper left hand corner of its respective pocket (see figure 5).

NOTES: **Place these devices in the elevator tray in accordance with the "random sequence number" as delineated in the matrices shown in figures 5 and 6.**

Extreme care must be taken to not contact the leads of these formed devices as this could possibly induce an offset in the component placement that would skew the experimental results!

17. Adjust the preparation side trim die to accept the Kyocera 132-pin FPD (# PB-F86259).

18. At the placement side controller, load the program named "FORM.BBF."

19. Load the 8 as received Kyocera packages into tray #1 of the preparation side parts elevator with pin #1 of each component in the upper right hand corner of its respective pocket (see figure 5).

20. Reset the feeder and start the board build cycle to form these eight (8) devices.

NOTE: **The "FORM.BBF" file only forms eight (8) devices at one time.**

21. Load the 8 aged Kyocera packages into tray #1 of the preparation side parts elevator with pin #1 of each component in the upper right hand corner of its respective pocket (see figure 5).

22. Reset the feeder and then re-initiate the board build file to form the last eight (8) devices.

23. Carefully load these formed devices in elevator tray #12 of the workcell placement side part elevator with the "as received" devices situated in the two (2) left feeder columns and the "aged" devices situated in the two (2) right feeder columns. Pin #1 of each device shall be located in the upper left hand corner of its respective pocket (see figure 5).

NOTES: Place these devices in the elevator tray in accordance with the "random sequence number" as delineated in the matrices shown in figures 5 and 6.

Extreme care must be taken to not contact the leads of these formed devices as this could possibly induce an offset in the component placement that would skew the experimental results!

J. Load the components into appropriate feeders in accordance with the following table:

NOTE: The fine pitch devices have already been loaded as per previous steps!

Table 13

Component P/N	Feeder No.	Elevator Tray
IRK32F1-200B		
IRK32F1-200B (aged)		
PB-C85124	TBD	
PB-C85124 (aged)		
PB-44823		
PB-44823 (aged)		

Table 13 (continued)

Component P/N	Feeder No.	Tape Feeder

49BCP

CDR02BX103BKURT   **TBD**

M55342K06B-110BR

K. At the placement controller, load either the "PLCE.BBF" file (for as received component selection) or the "AGED.BBF" file (for aged component selection), depending on the type of components to be placed, in accordance with the random sequence numbers of the applicable experimental run matrix.

L. Set up the 24-ASP stencil printer with the appropriate reference PWB, P/N 786582B, manufacturers S/N B79.

M. Using the Metech solder paste and refering to the initial run experimental matrix (table 5), print the appropriate PWB for the experimental run to be performed. Visually inspect the PWB to assure the quality of the deposit.

N. Measure the deposit thickness with the Microscan at the indicated component pads and record this data in table 14. Figure 2 shows the PWB orientation and the proper X and Y measurement conventions.

NOTE: **The PWB pad measurements must be completed within the "solder paste air exposure time" limits.**

O. After allowing for any "open time", place the pasted PWB onto the workholder shuttle and initiate the board build sequence. For those runs that require a "thick" PWB, place a 0.010" shim onto the workholder prior to the appropriate pwb.

P. Repeat steps M thru O until all 8 experiments have been completed for the initial run.

Q. Refering to the reflection experimental design matrix (table 6) run a reflected set of experiments in accordance with steps K through P of this section.

VI. RESPONSE DATA

NOTES: **All measurements for X and Y are stated relative to the board orientation as shown in figure 3. The actual offset measurement conventions are delineated in figure 6.**

All height mesurements are relative to the PWB surface.

Chip Component Offset Measurement   CLCC Offset Measurement   FPD Offset Measurement

Figure 6
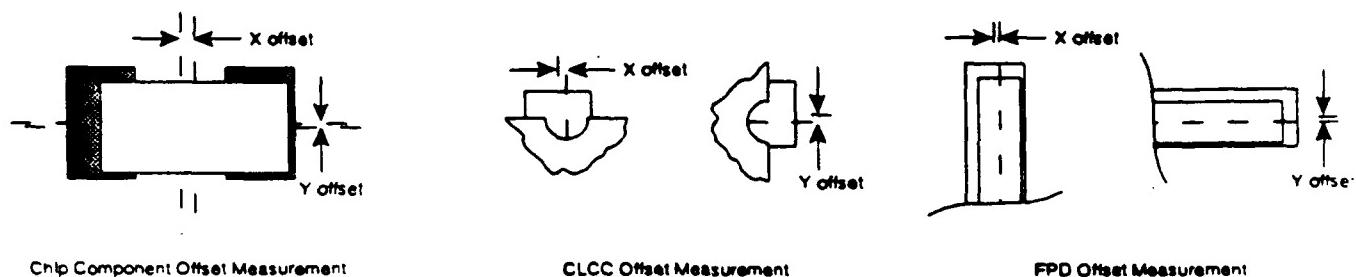
A. Lead/Pad Alignment

1. Measure and record the fine pitch component lead placement misregistration for each of the 8 experimental runs at the locations listed in Table 15. Use a filar eyepiece on a microscope with a precision of at least 0.2-mil.

2. Measure and record the 20-pin LCC component termination placement misregistration for each of the 8 experimental runs at the locations listed in Table 16. Use a filar eyepiece on a microscope with a precision of at least 0.2-mil.

3. Measure and record the 28-pin LCC component termination placement misregistration for each of the 8 experimental runs at the locations listed in Table 17. Use a filar eyepiece on a microscope with a precision of at least 0.2-mil.

4. Measure and record the 32-pin LCC component termination placement misregistration for each of the 8 experimental runs at the locations listed in Table 18. Use a filar eyepiece on a microscope with a precision of at lease 0.2-mil.

5. Measure and record the chip component termination placement misregistration for each of the 8 experimental runs at the locations listed in Table 19. Use a filar eyepiece on a microscope with a precision of at least 0.2-mil.

6. Repeat steps 1 through 5 for the 8 reflection experimental runs.

NOTE: **Tables 16 through 19 are designed for the collection of data for both the initail and the reflected experimental runs.**

B. Lead Pentration

1. Measure the penetration of designated component leads into the solder paste deposit for each of the eight experimental runs as follows:

   a. Utilizing the Microscan meaure and record the height of the CLCC's and the chip components relative to the bare PWB material at the designated pins in accordance with table 20.

   b. Utilizing the Microscan meaure and record the height of the fine pitch device leads relative to the bare PWB material at the designated pins in accordance with table 20.

   c. Remove the designated chip components from their pwb's in accordance with table 21, clean the components, and measure their height using a dial micrometer with a resolution of at least 0.1 mil. Record this data in table 21 under the proper headings taking extreme care to verify the component reference designator and its initial orientation on the board.

Table 14

Solder Paste Deposit height (measure the solder paste height at the center of the indicated pad)
One Sheet for Each PWB

PWB S/N_____

Discrete Components

	Solder Paste Height (mils)	
Ref Des	Pad 1	Pad 2
R10		
R16		
C21		
C31		
C45		
C46		

20 Pin CLCC

	Solder Paste Height (mils)			
Ref Des	Pad 3	Pad 8	Pad 13	Pad 18
U28				

28 Pin CLCC

	Solder Paste Height (mils)			
Ref Des	Pad 4	Pad 11	Pad 18	Pad 25
U22				

32 Pin RCLCC

	Solder Paste Height (mils)			
Ref Des	Pad 4	Pad 13	Pad 20	Pad 29
U7				

132 Pin Fine Pitch Devices

	Solder Paste Height (mils)		
	Reference Designator		
	U 1	U 20	U 39
Pad 1			
Pad 2			
Pad 3			
Pad 34			
Pad 35			
Pad 36			
Pad 67			
Pad 68			
Pad 69			
Pad 100			
Pad 102			
Pad 103			

Table 15
Fine Pitch Device Placement Misregistration

PWB S/N_____

U 1   Component S/N _____

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
1			
2			
3			
34			
35			
36			
67			
68			
69			
100			
101			
102			

U 20   Component S/N _____

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
1			
2			
3			
34			
35			
36			
67			
68			
69			
100			
101			
102			

U 39   Component S/N _____

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
1			
2			
3			
34			
35			
36			
67			
68			
69			
100			
101			
102			

Table 16

20 - Pin CLCC Placement Misregistration

PWB S/N_____

U 2   Component S/N _____

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
3			
8			
13			
18			

U 5   Component S/N _____

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
3			
8			
13			
18			

U 19   Component S/N _____

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
3			
8			
13			
18			

U 28   Component S/N_____

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
3			
8			
13			
18			

U 33   Component S/N_____

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
3			
8			
13			
18			

Table 17

28 - Pin CLCC Placement Misregistration

PWB S/N_____

U 22   Component S/N_____

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
11			
18			
25			

U 30   Component S/N_____

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
11			
18			
25			

U 35   Component S/N_____

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
11			
18			
25			

U 38   Component S/N_____

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
11			
18			
25			

Table 18

32 - Pin RCLCC Placement Misregistration

PWB S/N_____

U 7   Component S/N _____

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
13			
20			
29			

U 12   Component S/N_____

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
13			
20			
29			

U 14   Component S/N_____

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
13			
20			
29			

U 34   Component S/N_____

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
13			
20			
29			

Table 19

Chip Component Placement Misregistration

PWB S/N_____

Refer. Designator	X - Offset (mils)	Y - Offset (mils)	Remarks
R 01			
R 06			
R 10			
R 16			
R 24			
R 31			
R 33			
C 01			
C 14			
C 15			
C 21			
C 23			
C 31			
C 32			
C 40			
C 41			
C 42			
C 43			
C 44			
C 45			
C 46			
C 47			
C 48			

VII. DATA REDUCTION

3. Using the data gathered by this experiment, the response sheets typified by Table 3 will be completed for each response; and significant interstation process variables will be identified.

4. Additional statistical analyses of the data using analysis of variance (ANOVA) techniques will yield variability, experimental error, and process capability indices data.

Table 20

Placed component/lead height (measure the component /lead height at the center of the indicated pad)
One Sheet for Each PWB

PWB S/N _____

Discrete Components

	Compnent Height (mils)	
Ref Des	Pin 1	Pin 2
R10		
R16		
C21		
C31		
C45		
C46		

20 Pin CLCC

	Compr Height (mils)			
Ref Des	Pin 3	Pin 8	Pin 13	Pin 18
U28				

28 Pin CLCC

	Component Height (mils)			
P Des	Pin 4	Pin 11	Pin 18	Pin 25
U22				

32 Pin RCLCC

	Component Height (mils)			
Ref Des	Pin 4	Pin 13	Pin 20	Pin 29
U7				

132 Pin Fine Pitch Devices

	Component Lead Height (mils)		
	Reference Designator		
	U 1	U 20	U 39
Pin 1			
Pin 2			
Pin 3			
Pin 34			
Pin 35			
Pin 36			
Pin 67			
Pin 68			
Pin 69			
Pin 100			
Pin 102			
Pin 103			

Table 21

Chip Component Heights

PWB Serial #	R10		R16			C21			C31			C45			C46		
	Pin 1	Pin 2	avg	Pin 1	Pin 2	avg	Pin 1	Pin 2	avg	Pin 1	Pin 2	avg	Pin 1	Pin 2	avg	Pin 1	Pin 2	avg
582A S/N 1001																		
582A S/N 1002																		
582A S/N 1003																		
582B S/N 1101																		
582B S/N 1102																		
582B S/N 1103																		
582B S/N 1104																		
582B S/N 1105																		
582C S/N 1201																		
582C S/N 1202																		
582C S/N 1203																		
582C S/N 1204																		
582C S/N 1205																		
582D S/N 1301																		
582D S/N 1302																		
582D S/N 1303																		

Component Reference Designator

Appendix G

Single Point Experiment: FPD Placement

SINGLE POINT EXPERIMENT

FPD PLACEMENT

I.   INTRODUCTION

This document presents the detailed experimental plan and procedures for performing the single point FPD placement experiment. This experiment is being run, because of the serious problems encountered placing FPDs during the execution of the Subtask 5, Experiment No. 2, Detailed Experimental Plan within the specification limits presented in Table 1.

The conclusions reached from that experiment were that the Gelzer robot could neither accurately nor precisely locate the local fiducials associated with the FPD pad patterns on the PWB. The difficulty is thought to be due to the fact that two component pad pattern pads with attached traces and plated through holes (see Figure 1a) were selected to double as local fiducial patterns. It appears that the robot's vision system is not able to handle these. A fix was introduced into the original experiment in which a shoulder pin was inserted into the plated through holes of these fiducials. This seemed to improve the robot's ability to recognize the pattern, however there was too much variability encountered. This variability is due to the fact that the location of the hole drilled in the pad pattern is not associated directly to the artwork feature. The drilled hole location precision is tied to tooling holes placed in the board fabrication panel and the precision of the drilling machine that forms the hole in the pad pattern.

Modifications were made to the basic EMPI PWB design to provide dedicated local fiducials for the three FPD pad patterns. See Figure 1 for the before and after conditions. Figure 1b shows the dedicated local fiducial design. This experiment, then, is designed to determine if the dedicated local fiducials in fact provide data to the robot that allows it to accurately and precisely place the FPDs. The accuracy and precision of this process will be quantified and used for establishing a Cpk index and yield.

Figure 1

EMP1 FPD Pad Pattern Local Fiducials

PAD PATTERN VIA USED
AS A FIDUCIAL
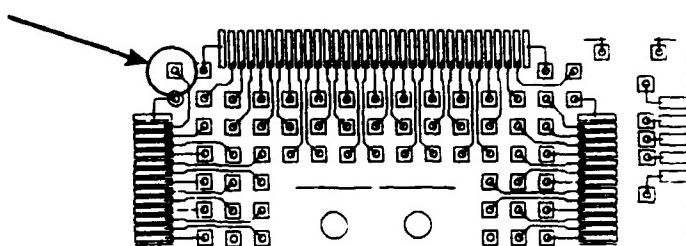
(a)

DEDICATED FIDUCIAL
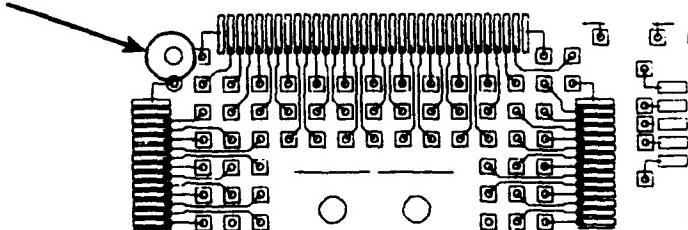
(b)

Table 1. Response variable details.

Response Variable	Measuring Device/ Precision	Specification Limit	Specification
C. FPD lead and toe overhang	+/- 0.2 mils	25% of lead width, max or 20 mils, max; whichever is greater	MIL-STD-2000

II.   MATERIALS AND SUPPLIES

PWB (Two each of the following)

P/N	S/N	Description
786582/A	3100, 3101	Solder dipped hot air leveled,
786582/C	3110, 3111	Tin-lead plate and fuse

Component

Qty	P/N	Description
12	IMKX3F1-4546AA	NTK 132-pin FPD

Supplies

Unsupported adhesive film	3M

<u>Solvents</u>

Isopropyl alcohol   TT-I-335
1,1,1-trichlorethane   MIL-T-81533

III.   TOOLS AND EQUIPMENT

General purpose stereo microscope, 0.7x-3x zoom with an American Optical No. 424, 10x-filar eyepiece and a Trimos vertical digital readout.

Batch & In-Line Vapor Degreaser   Baron-Blakeslee, Inc.
Models MLR-120 & CBL-18   2001 N. Janice Ave.
(as noted or equiv.)   Melrose Park, IL 60160

Laser Profilometer   CyberOptics Corp.
Microscan   2331 University Ave., SE
                              Minneapolis, MN   55414

Robotic Preparation and   Gelzer Systems
Placement Workcell   425 Enterprise Drive
Model 1312   Westerville, OH 43081

IV.   **ROBOTIC PLACEMENT PROCESS OVERVIEW**

During the course of a printed wiring assembly build cycle, several functions are performed by the workcell in a logical sequence. The following are brief explanations of those functions, offered in the same order in which the workcell performs them.

A.   **BOARD BUILD FILE DOWNLOAD**

1.   Board build files are comprised of the PWB CAD data which specifies component and fiducial locations, component part numbers and component orientation. Also included in the file are certain PWB attributes such as PWB thickness and presentation orientation. The required board build file is, on demand, loaded to active memory from either the main storage disk (hard drive) or the VAX host.

2.   The loaded file is then reviewed in the controller to verify that component feeders have been designated and that component description files are in place for all part numbers existing in the file.

B.   **BOARD BUILD SEQUENCE**

1.   The PWB is loaded onto the workholder, the cycle is initiated and the PWB is shuttled into the workcell so that it may be accessed by the robotic arm.

2.   A downward looking camera locates the global fiducials and generates the pattern offset for the PWB.

3.   The required nozzle is obtained by the robotic arm and the build sequence begins as delineated in the board build file.

4.   Each component is picked up, in the designated sequence, vision inspected (see description below) for orientation and geometry and then placed on its respective pad pattern with offset compensation applied.

5.   This process continues until all parts have been placed at which time the completed assembly is shuttled back out of the workcell where it is once again accessable to the operator.

C. **VISION INSPECTION**

LEADED COMPONENTS

The vision algorithm for the 132-pin ceramic quad flatpacks (CQFP's) is designed to create a silhouette of the components leads. The silhouette is created by backlighting the component via an ultra-violet illuminator and a luminescent surface situated directly behind the component and attached to nozzle. Six leads to either side of a component body corner are viewed and utilized to locate that corner with respect to the lead outline. This process is repeated for the remaining three corners (the component is rotated three times) and the derived corner locations are used to derive the centroid of the lead outline and its orientation (offset).

V.   PROCEDURE

A.   Preliminary

1.   Clean the serialized PWBs in the in-line vapor degreaser.

2.   Clean all of the components in a vapor degreaser.

3.   Place a piece of unsupported adhesive film on the middle five pads of each side of the FPD pad patterns. Use PIN 786582/1, SN 3100 and 3101 and PIN 786582/C, SN 3110 and 3111.

NOTE: Gloves or finger cots must be worn for all PWB and component handling from this step on and continued until all components have been placed.

Prior to an experimental run set up the forming die to give a belly-to-toe dimension of 8-10 mils. Do this by measuring and recording the body thickness of an NTK part at the locations indicated in Figure 2. Record the data in Table 2. Form the part in the robot, place it on a surface plate, and measure the height of the top of the package body from the surface plate using a surface gauge precise to +/- 0.1 mils. This second measurement shall be taken at the same locations indicated by Figure 1. Enter this data in Table 3. The belly-to-toe height will be the averaged differences between the formed and 'as-is' measurements taken. Calculate this value and record it in Table 4. Repeat this procedure until the 8- to 10-mil dimension is achieved.

B. Placement

Form and tin 12 NTK FPD's as follows:

NOTE: The FPD leads are inspected by backlighting the leads to create a silhouette of the leads. The presence of solder on the lead does not affect the robots ability to accurately place the device. See Figure 3 for the locations of the U1, U20, and U30 FPD pad patterns.

Figure 2

FPD Package Measurement Locations


Pin 132   Pin 100

Pin 1 Indicator —

Pin 1

Pin 99

NTK
F132-01

Pin 33

Pin 67

NOTE: Pin count runs counterclockwise
around package when viewed
from the package top.

Typical Serial
Number location
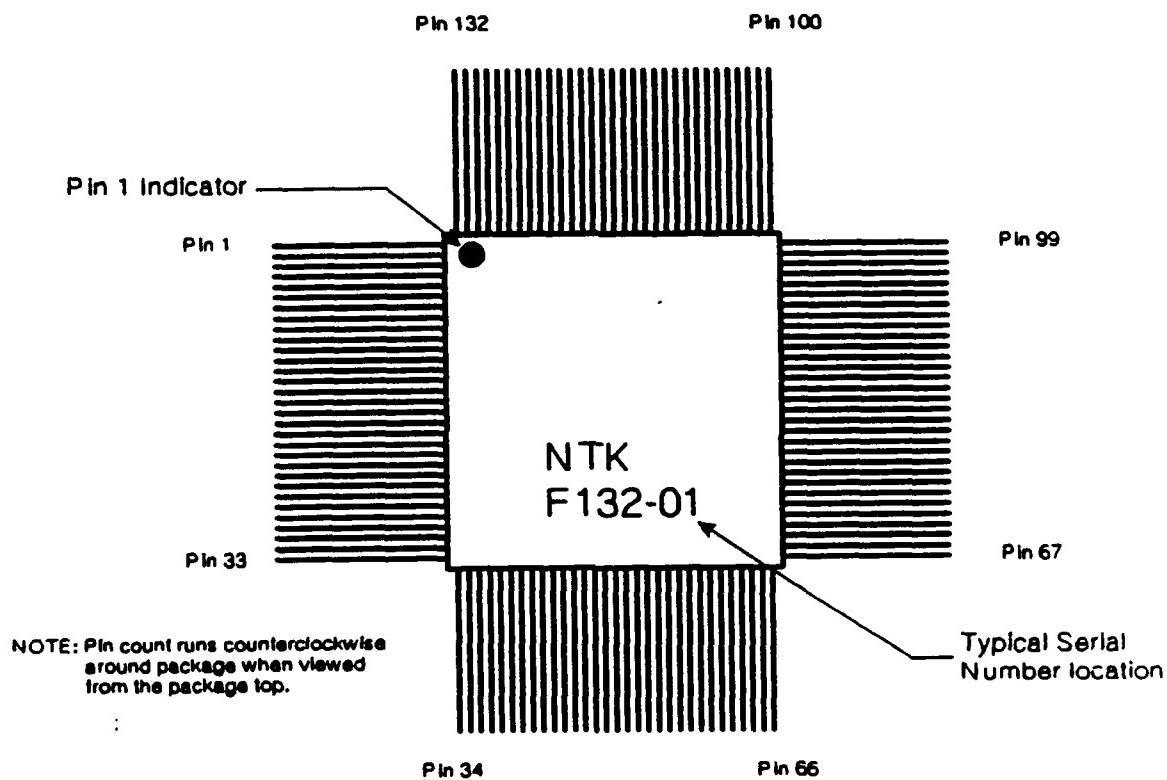
Pin 34   Pin 66

Table 2

NTK Package Body Thickness

Serial No.	Pin 1	Pin 34	Pin 67	Pin 100	Body Center

Table x

NTK Package Body Height After Forming

| Serial No.	Pin 1	Pin 34	Pin 67	Pin 100	Body Center

Table x

NTK Package Belly-to-Toe Dimension

Serial No.	Pin 1	Pin 34	Pin 67	Pin 100	Body Center	Avg

Figure 3

PWB Measurement Orientation

Global Fiducials, 3 Locations, Typical
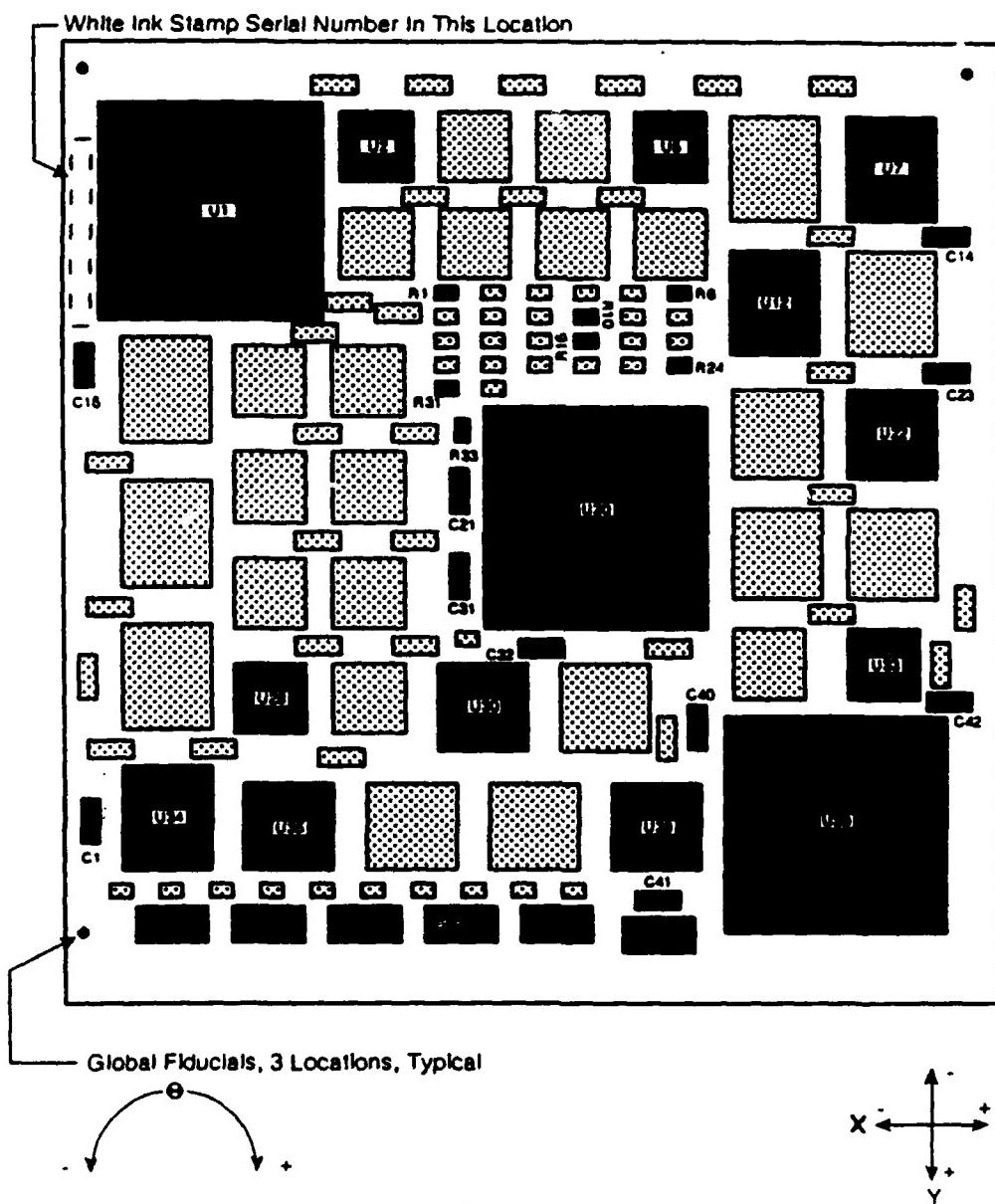
1. Energize the Gelzer Model 1312 robotic workcell as per EOP10160.

2. Turn on the solder pot.

3. When the solder pot comes up to temperature, turn on its pump and adjust the height of the fountain using the fountain height gauge.

4. Turn on the nitrogen supply to the solder pot.

5. Reset the L132 compont description file at the preparation side controller to trim, form, and inspect only.

6. Adjust the preparation side trim die to accept the NTK 132-pin FPDs.

7. At the placement side controller, load the program named "SINGLE_POINT.BBF.

8. Load the 12 NTK packages into tray #1 of the preparation side parts elevator with pin #1 of each component in the upper right hand corner of its respective pocket (see Figure x).

9. Start the board build cycle and form, tin, and place these twelve (12) devices, 3 each, on PIN 786582/A, SN 3100 and 3101 and PIN 786582/C, SN 3110 and 3111.

Figure 4

Prep Side Elevator Tray and Component Orientation

This edge faces the robot arm

PIN 1 LOCATION, 16 PLACES, TYPICAL

4	3	2	1
8	7	6	5
12	11	10	9
16	15	14	13
20	19	18	17
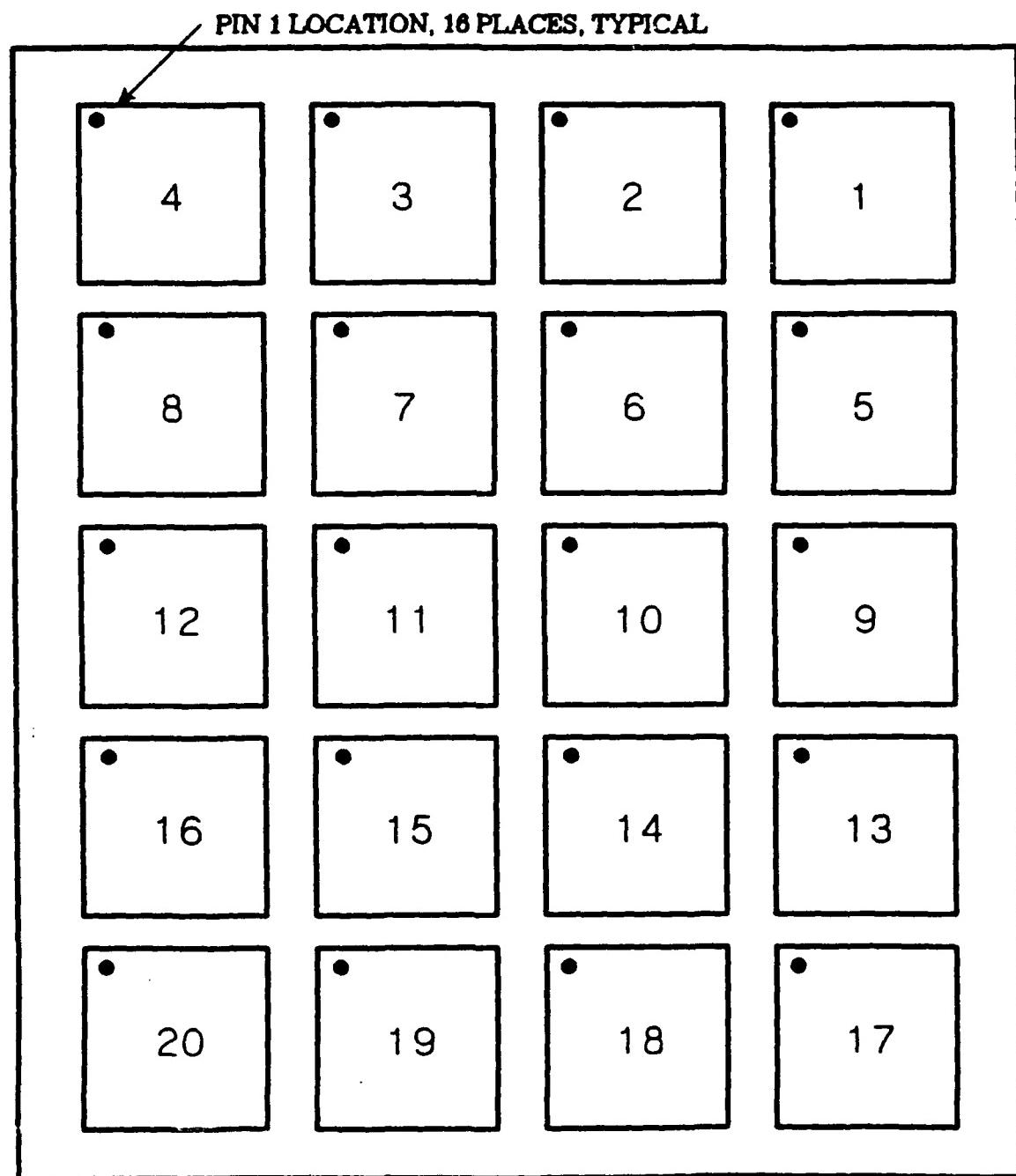
VI. RESPONSE DATA

1. All measurements for X and Y are stated relative to the board orientation as shown in Figure 3.

2. The actual offset measurement conventions are delineated in Figure 5.

3. Measure and record the fine pitch component lead placement misregistration for each of the 4 experimental runs at the locations listed in Table xx. Use a filar eyepiece on a microscope with a precision of at least 0.2-mil.

Figure 5

FPD Offset Measurement
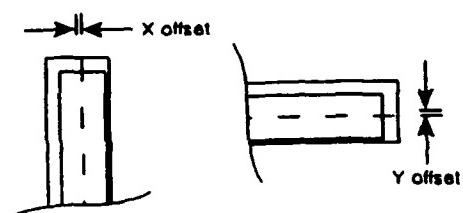
FPD Offset Measurement

Table 5

FPD Placement Misregistration Data

PWB S/N_____

U 1

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
1	▓		
2	▓		
3	▓		
34		▓	
35		▓	
36		▓	
67	▓		
68	▓		
69	▓		
100		▓	
101		▓	
102		▓	

U 20

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
1	▓		
2	▓		
3	▓		
34		▓	
35		▓	
36		▓	
67	▓		
68	▓		
69	▓		
100		▓	
101		▓	
102		▓	

U 39

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
1	▓		
2	▓		
3	▓		
34		▓	
35		▓	
36		▓	
67	▓		
68	▓		
69	▓		
100		▓	
101		▓	
102		▓	

VII.   DATA REDUCTION

1.   Using analysis of variance (ANOVA) techniques determine the mean, standard deviation, variability, Cpk, and yield for this process.

Appendix H

Final Run

Interoffice Correspondence
TRW Avionics & Surveillance Group

TRW

I. INTRODUCTION

This IOC presents the detailed experimental plans and procedures for performing the experimental procedure for the final EMPI PWA process. This experiment is designed to identify significant inter-workstation process variables that effect several responses for the PWA Assembly process. It incorporates information from runs on seven previous experiments.

The significant process variables were identified in a 'brain storming' session among several manufacturing and process engineers. Figure 1 presents the cause and effect diagram that resulted from that 'brain storming' session and identifies the process variables and responses for this final PWA process run. The encircled process variables are those being evaluated in this experiment. The other process variables were previously evaluated.

Ranges (or levels) for the process variables were selected based on tolerances that were expected to be encountered on the factory floor. These ranges, the instruments used to measure the variables, and the reference to the source for the ranges are presented in Table 1. An asterisk identifies those process variables being evaluated by this experiment. Responses to be analyzed for this final run, the instruments used to measure the responses, the specification limits for the responses, and the source for the specification limits are presented in Table 2. This experimental design is a full factorial with three process variables. Columns AB, AC, BC, and ABC are be used for interaction and experimental error measurements. One replicate will be run so that the process variability can be determined along with the process capability index, Cpk, and the process yield. Table 3 presents the form that will be used for each response evaluated by this experimental design.
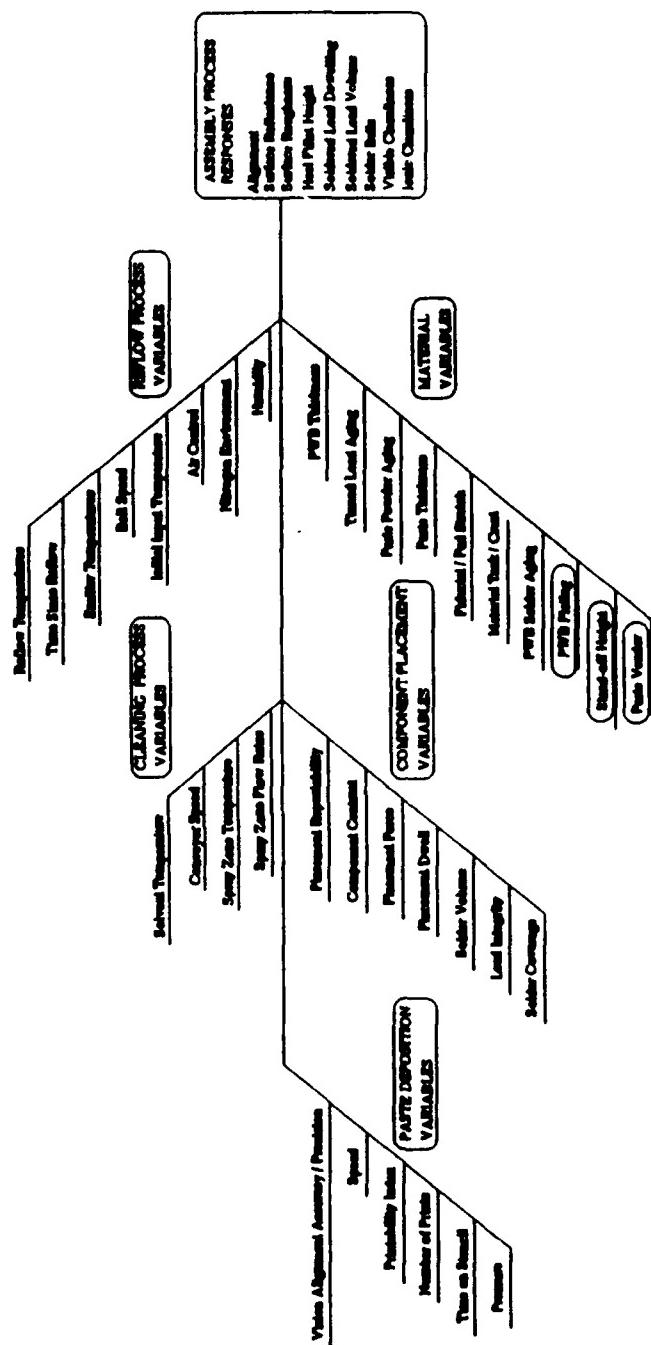
Figure 1

Final EMPI Printed Wiring Assembly Run
Cause And Effect Diagram

Table 1

Process Variable Details

Process Variable	Measuring Device/ Precision	Variable Range	Specification
Time since reflow	Timer/ +/- 1 min	0 to 30 mins	ST3E2 experiment
Reflow temperature	Thermocouple/ +/- 1 deg C	208 to 212 deg C	ST1E0 experiment
Nitrogen environment	Oxygen analyzer/ +/- 2 percent	70 to 98 percent	ST3E2 experiment
Component stand-off height	Light section microscope +/- 0.2 mils	4 to 6 mils	ST3E2 experiment
Solder paste vendor	not applicable	Metech and Multicore	ST5E1 experiment
Solvent temperature	Thermocouple/ +/- 1 deg C	140 to 160 deg F	Baseline document
Conveyor speed	Common operator inter- face/+/- 0.1 fpm	1 to 3 fpm	Baseline document
Spray zone temperatures	Common operator inter- face/+/- 1 psi	40 to 50 psi and 170 to 190 psi **	Baseline document
PWB plating style	N/A	solder dipped and hot air leveled and Sn/Pb plate and fused	ST1E0
FPD lead skew	+/- 1 mil	as received	Engineering drawing
FPD lead aging	N/A	less than 1 yr	ST2E0 experiment

H-5

Table 1, concluded

Process Variable Details

PWB aging	N/A	less than 1 yr	ST1E0 experiment
Package type	N/A	Kyocera	ST4E0 experiment
Solder paste aging	N/A	as received	ST1E0 experiment
Belly-to-toe dimension	surface gauge +/- 0.2 mils	11 +/- 1 mil	ST2E0 experiment
Flux density	Sensby system +/- 0.001	0.885 to 0.895	Baseline document
Tinning solder temperature	Robot cntrlr +/- 1 deg F	490 to 510 F	MIL-STD-2000
Wave smoothness	Visual	0 to minor turbulence	Baseline document
Nitrogen flow	Flow meter +/- 1 scfh	40 and 100 scfh	ST1E0 experiment
Coplanarity	Microscan +/- 0.1 mil	+/- 4 mils	ST4E0 experiment
Toe-to-toe	as formed	1.225 +/- 0.005 in	ST4E0 experiment
Toe angle	as formed	0 +/-15 deg	ST4E0 experiment
Toe burrs	as formed	1x lead thick (5 mils)	ST4E0 experiment
Solder paste open time	timer +/- 1 sec	0.5 to 3 hrs	ST5E2 experiment
Fiducial pad stretch	+/- 0.1 mils	+/- 3 mils from A/W dim	ST5E2 experiment
Placement force	force gauge +/- 1 gm	5 to 50 gm per lead	ST5E2 experiment
PWB thickness	dial microm. +/- 0.1-mil	58 to 68 mils	ST5E2

* Process variable being studied by this experiment

Table 2

Response Variable Details

Response Variable	Measuring Device/ Precision	Specification Limit	Specification
Visual cleanliness	Comparison to visual standards/ +/- 1 unit	1 to 5 units	MIL-P-28809
Ionic cleanliness	Ionic contam- ination test- er/+/- 1 ugm NaCl/sq in	0 to 10 ugm NaCl/sq in	MIL-C-28809
Solder joint roughness	Comparison to visual standards/ +/- 1 unit	1 to 5 units	MIL-P-28809
Solder joint reflectance	Comparison to visual standards +/- 1 unit	1 to 5 units	MIL-P-28809
Heel fillet height	Microscope with filar +/- 0.1-mil	0 to 100% of calf length	MM 3-23
Soldered lead dewetting	Microscope with particle counting grid	0 to 5 % of soldered area	MM 3-22

Table 2

Response Variable Details

Soldered lead soldered fillet volume	visual comparison	No lead-to-pad fillet extending over top of lead foot and beyond edge	MM 3-21 and MM 3-22
Solder balls	Microscope with filar +/- 0.1-mil	5 mils, max	MM 5-6
Lead-to-pad alignment	Microscope with filar +/- 0.1-mil	+/- 25% of lead width (+/- 2.75 mils)	MIL-STD-2000

Table 3

Response Table With Interaction Effects

Random Order Trial Number	Standard Order Trial Number	Response Observed Value	A		B		C		AB		AC		BC		ABC	
			1	2	1	2	1	2	1	2	1	2	1	2	1	2
	1															
	2															
	3															
	4															
	5															
	6															
	7															
	8															
TOTAL																
NUMBER OF VALUES																
AVERAGE																
EFFECT																

II. MATERIALS AND SUPPLIES

PWB.-

Qty	PIN	Description
8	786582/A	Solder dipped and hot air leveled
8	786582/C	Sn/Pb plate and fused

Components.-

Qty	PIN	Description
48	PB-F36259	132-pin, Kyocera, FPD package
288	PB-C85124	20-pin, LCC
160	PB-44823	28-pin, LCC
128	IRK32F1-200B	32-pin, RLCC
608	M55342K06B-110BR	M55342/6, chip resistor
672	CDR02BX103-BKURT/BKUS	CDR02, chip capacitor
96	49BCP	CWR06, chip capacitor

Solder Paste.-

Metech RHF63	Metech, Inc Route 401 Halverson, PA 19520
Multicore SN62RM92A90	Multicore Solders Cantiague Rock Road Westbury, NY 11590

Stencil.-

T786582-6/1	6/12 thickness

Dry Film Solder Mask.-

Vacrel 8100	E.I. DuPont de Nemours Wilmington, DE

Solder Mask Artwork.-

T786582-5/1   0.020-in diameter standoff pattern

Miscellaneous.-

Palette knife, plastic   Holbein

Bristle brush

Shamis 99-150 cleaning cloth   Affiliated Manufacturers, Inc.

96244 Protective gloves   Jones Associates

Solvents.-

Isopropyl alcohol   TT-I-335

1,1,1-Trichloroethane   MIL-T-81533

III TOOLS AND EQUIPMENT

General purpose stereoscope, 0.7X to 3X zoom with an American Optical No. 424,
10X, filar eyepiece

Screen Printer No. 24-ASP   MPM Corporation
                                     10 Forge Park
                                     Franklin, MA 02038

Malcom Viscometer   Austin American Technology
                                     12201 Technology Blvd.
                                     Austin, TX 78727

Gelzer Robot   Gelzer Systems
                                     Westerville, OH

In-Line Cleaner, CBL-18   Baron Blakeslee
                                     2001 N. Janice Ave.
                                     Melrose Park, IL 60160

Vapo-Kleen Stencil Cleaner,   Universal Electronics, Inc.
Model No. 1110187

Microscan   CyberOptics Corp.
                                     2331 University Ave. S.E.

Minneapolis, MN 55414

IR Reflow Oven, Model SMD 722

Vitronics Corp
40 Forge
Haymarket, NH

Ionic Contamination Tester
Model ICOM 4000

Westek, Inc.
400 Rolyn Place
Arcadia, CA 91006

IV PROCEDURE

A. Eight Run Full Factorial Design with One Replicate

Note: Select 8 786582/A PWBs and serialize them as 3001 through 3004 and 3011 through 3014. Select 8 786582/C PWBs and serialize them as 3006 through 3009 and 3016 through 3019. Set aside for the experiment and its replicate.

1. Initial 'normal' experiment

a. Create one worksheet similar to the one shown in Table 3, for each of the responses listed in Table 2, that are to be monitored. Column A is assigned to 'Standoff Height'; sub-column 1 is for '4 mils'; sub-column 2 is for '6 mils'. Column B is assigned to the 'PWB Plating Type'; sub-column 1 is for 'hot air leveled'; sub-column 2 is for 'fused'. Column C is assigned to the 'Solder Paste Vendor'; sub-column 1 is for 'Metech'; subcolumn 2 is for 'Multicore'. Columns AB, AC, BC, and ABC are reserved for interaction and experimental error determinations. See Tables 15 and 16.

b. Run the experimental trials for this initial experiment using the random number sequence listed in the "Random Order Trial Number" column of Table 15.

c. Clean the appropriate, serialized PWBs in the in-line solvent cleaner.

d. Set up the 24-ASP stencil printer with an appropriate reference PWB. Keep in mind that different solder paste vendors are being applied to different boards depending on the run number.

e. Set up the component preparation and placement sides of the Gelzer robot.

f. Set up the CBL-18 in-line cleaner with the appropriate PWA cleaning process profile (Profile No.1).

g. Select the PWB, solder paste, and standoff parameters required for the run identified as random number 1 in Table 15.

h. Stencil print the PWB forcing the desired material vendor as required by the test matrix.

i. Place the printed PWB in the Gelzer robot load station and form, trim, tin, and place the selected FPD and all other components using the nominal placement values for all components. Other than the CWR06 parts, chip components need not be placed.

j. Reflow the PWA subassembly in the IR reflow oven using nitrogen and the 210 EMPI profile (No. 34).

       k. Clean the PWA in the CBL-18 in-line cleaner using the PWA cleaning profile no. 1.

       l. Repeat steps IV.A.1.c through IV.A.1.k, inclusive, until all 8 experimental runs have been completed for this initial experiment.

    3. Second Replication Experiment

       a. Using the test parameters and the random order sequence specified by the Table 16 matrix for a second replicated run, repeat steps IV.A.1.b - IV.A.1.l.

V. RESPONSE DATA

A. Visual Cleanliness

1. Scan the entire PWA and compare and rank the cleanliness against the visual standards presented in Figure 2. Record the data in Table 4.

B. Ionic Contamination

1. Measure the cleanliness of the PWA using the Westek ICOM 4000. Record the data in Table 4.

Figure 2

Visual PWA Cleanliness Standards

0 NO CONTAMINATION VISIBLE REGARDLESS

   OF LIGHT OR MAGNIFICATION (MAX 30X)

1 EDGE OF VISIBILITY, TRANSPARENT

   DRY RESIDUE

2 EASILY VISIBLE, TRANSPARENT DRY

   RESIDUE

3 OPAQUE, WHITE DRY DEPOSIT

4 LIGHT DEPOSIT OF WET FLUX

5 HEAVY DEPOSIT OF WET FLUX

H-15
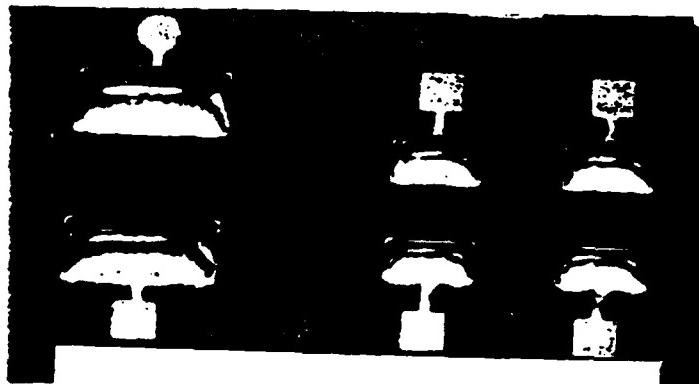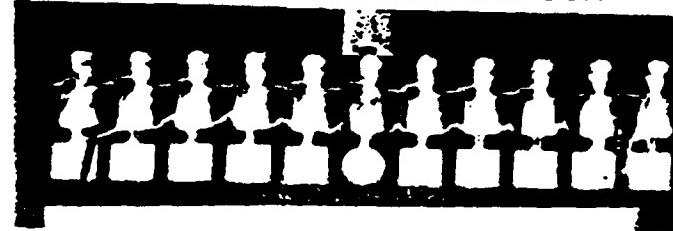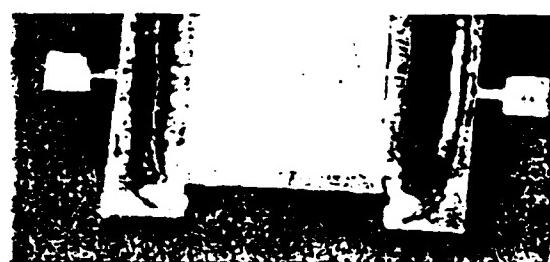
Table 4

Data Collection Table for PWA Cleanliness

PWB SN	CLEANLINESS		COMMENTS
	VISUAL, 0-5	IONIC, Mg NaCl/in2	
3001			
3002			
3006			
3007			
3011			
3012			
3016			
3017			
3003			
3004			
3008			
3009			
3013			
3014			
3018			
3019			

C. FPD Lead-to-Pad Alignment

1. Measure the lead-to-pad alignment as shown in Figure 3 and record the data in Table 5.

D. LCC Termination-to-Pad Alignment

1. Measure the termination-to-pad alignment for the 20-, 28-, and 32-pin LCC packages as shown in Figure 4. Record the data for the packages shown in the applicable Tables 6 through 8.

E. Solder Joint Reflectance

1. FPDs

  a. Measure the solder joint reflectance of the U01 and U20 FPD package pins and record the results in Table 9. Use the visual standards as presented in Figure 5.

2. LCCs

  20-Pin LCCs

  a. Measure the solder joint reflectance of the U04, U19, and U33 LCC package terminations and record the results in Table 10. Use the visual standards as presented in Figure 5.

  28-Pin LCCs

  a. Measure the solder joint reflectance of the U22, U30, and U32 LCC package terminations and record the results in Table 11. Use the visual standards as presented in Figure 5.

  32-Pin LCCs

  a. Measure the solder joint reflectance of the U07, U17, and U34 LCC package terminations and record the results in Table 12. Use the visual standards as presented in Figure 5.

F. Solder Joint Roughness

1. FPDs

  a. Measure the solder joint roughness of the U01 and U20 FPD package pins and record the results in Table 9. Use the visual standards as presented in Figure 6.

2 LCCs

H-17

20-Pin LCCs

a. Measure the solder joint roughness of the U04, U19, and U33 20-pin LCC package terminations and record the results in Table 10. Use the visual standards as presented in Figure 6.

28-Pin LCCs

a. Measure the solder joint roughness of the U22, U30, and U32 28-pin LCC package terminations and record the results in Table 11. Use the visual standards as presented in Figure 6.

32-Pin LCCs

a. Measure the solder joint roughness of the U07, U17, and U34 32-pin LCC package terminations and record the results in Table 12. Use the visual standards as presented in Figure 6.

G. FPD Solder Joint Heel Fillet Height

1. Measure the solder joint heel fillet height as shown in Figure 7 for the U01 and U20 FPD component leads. Record the data in Table 9. Data is reported as a percent of the total 'calf' length.

Figure 3

FPD Lead-to-Pad Offset Depiction
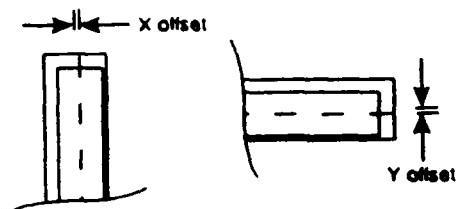
FPD Offset Measurement

Table 5

Fine Pitch Device Placement Misregistration

PWB S/N_____

U 01

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
1			
2			
3			
64			
65			
66			
67			
68			
69			
130			
131			
132			

U 20

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
1			
2			
3			
64			
65			
66			
67			
68			
69			
130			
131			
132			

Figure 4

LCC Castellation-to-Pad Offset Depiction
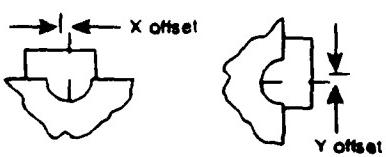
Table 6

20-Pin LCC Placement Misregistration

PWB S/N_____

U 04

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
3			
8			
13			
18			

U 19

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
3			
8			
13			
18			

U 33

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
3			
8			
13			
18			

Table 7

28-Pin LCC Placement Misregistration

PWB S/N_____

U 22

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
11			
18			
25			

U 30

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
11			
18			
25			

U 35

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
11			
18			
25			

Table 8

32-Pin LCC Misregistration

PWB S/N_____

U 07

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
13			
20			
29			

U 17

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
13			
20			
29			

U 34

Pad / Pin Number	X - Offset (mils)	Y - Offset (mils)	Remarks
4			
13			
20			
29			

Figure 5

Reflowed Solder Joint Reflectance

MAGNIFICATION 30X

a. (MM 3-4, top) Rank = 1

b. (MM 1-9, middle) Rank = 2

c. (MM 1-6, top) Rank = 3

d. (MM 3-22, top) Rank = 4

e. (MM 1-11, bottom) Rank = 5

Figure 6

Reflowed Solder Joint Roughness

a. (MM 3-42, mid-left) Rank=1

b. (MM 3-41, bt-rt) Rank=2
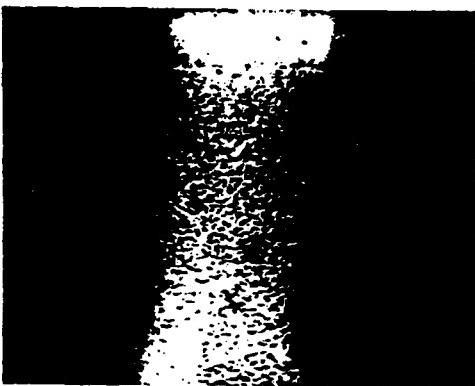
c. (MM 3-41, bt-lft) Rank=3

d. (MM 3-41, top-rt) Rank=4
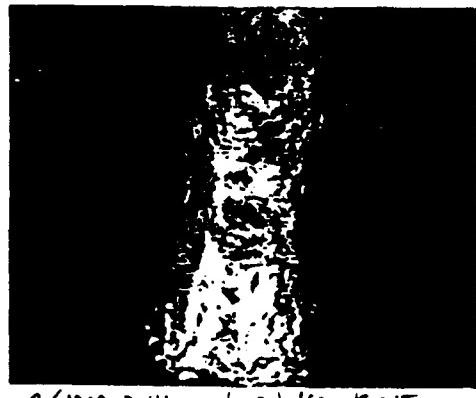
e (MM 3-41, mid-rt) Rank=5

Figure 7

FPD Solder Joint Lead Heel Fillet
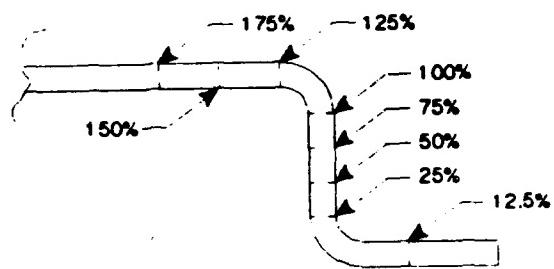
Table 9

FPD Solder Joint Appearance

PWB SN:

REF DES	LEAD NO.	REFLECT. RATING	ROUGH RATING	FILLET HEIGHT	COMMENTS
01	130				
	131				
	132				
	001				
	002	.			
	003				
	007				
	064				
	065				
	066				
	067				
	068				
	069				
20	130				
	131				
	132				
	001				
	002				
	003				
	007				
	064				
	065				
	066				
	067				
	068				
	069				

Table 10

20-Pin LCC Solder Joint Appearance

PWB SN:

REF DES	LEAD NO.	REFLECT RATING	ROUGH RATING	FILLET HEIGHT	COMMENTS
04	001				
	002				
	003				
	004				
	005				
	006				
	007				
	011				
	012				
	013				
	014				
	015				
	016				
19	001				
	002				
	003				
	004				
	005				
	006				
	007				
	011				
	012				
	013				
	014				
	015				
	016				

Table 10. concluded

20-Pin LCC Solder Joint Appearance

PWB SN:

REF DES	LEAD NO.	REFLECT. RATING	ROUGH RATING	FILLET HEIGHT	COMMENTS
01	001				
	002				
	003				
	004				
	005				
	006				
	007				
	011				
	012				
	013				
	014				
	015				
	016				

Table 11

28-Pin LCC Solder Joint Appearance

PWB SN:

REF DES	LEAD NO.	REFLECT. RATING	ROUGH RATING	FILLET HEIGHT	COMMENTS
	002				
	003				
	004				
	005				
22	006				
	007				
	016				
	017				
	018				
	019				
	020				
	021				
	002				
	003				
	004				
	005				
30	006				
	007				
	016				
	017				
	018				
	019				
	020				
	021				

Table 11. concluded

28-Pin LCC Solder Joint Appearance

PWB SN:

REF DES	LEAD NO.	REFLECT. RATING	ROUGH RATING	FILLET HEIGHT	COMMENTS
	002				
	003				
	004				
	005				
35	006				
	007				
	016				
	017				
	018				
	019				
	020				
	021				

Table 12

32-Pin LCC Solder Joint Appearance

PWB SN

REF DES	LEAD NO.	REFLECT RATING	ROUGH RATING	FILLET HEIGHT	COMMENTS
	002				
	003				
	004				
	005				
07	006				
	007				
	018				
	019				
	020				
	021				
	022				
	023				
	002				
	003				
	004				
	005				
17	006				
	007				
	018				
	019				
	020				
	021				
	022				
	023				

Table 12. concluded

32-Pin LCC Solder Joint Appearance

PWB SN:

REF DES	LEAD NO.	REFLECT. RATING	ROUGH RATING	FILLET HEIGHT	COMMENTS
	002				
	003				
	004				
	005				
34	006				
	007				
	018				
	019				
	020				
	021				
	022				
	023				

H. FPD Lead Dewetting

1. Examine the leads of the U01 and U20 FPD packages at 10x and map the dewet areas onto a grid. Record the percent dewet in Table 13. See Figure 8 for an example of a mapping grid.

I. FPD Solder Joint Volume

1. Examine the solder joints of the U01 and U20 FPD packages at 10x and rate the volume of the solder in the solder joints by comparing them against the standards shown in Figure 9. Record the results in Table 13.

J. Solder Balls

1. Transmission X-ray examine the assembled PWB after the in-line cleaning process. and locate the largest solder ball. Measure the diameter of the solder ball using a microscope with a filar eyepiece. Record the results in Table 14.

Table 13

FPD Solder Joint Volume and Dewetting

PWB SN:

REF DES	LEAD NO.	SOLDER		COMMENTS
		VOLUME	DE-WETTING	
	130			
	131			
	132			
	001			
	002			
	003			
01	007			
	064			
	065			
	066			
	067			
	068			
	069			
	130			
	131			
	132			
	001			
	002			
	003			
20	007			
	064			
	065			
	066			
	067			
	068			
	069			

Figure 8

FPD Soldered Lead Dewetting

Typical Non-Wet Area
(Viewed through grid)
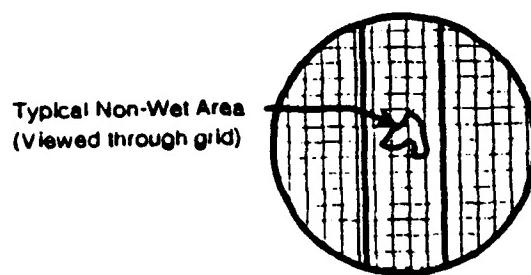
Figure 9

Reflowed Solder Joint Volume
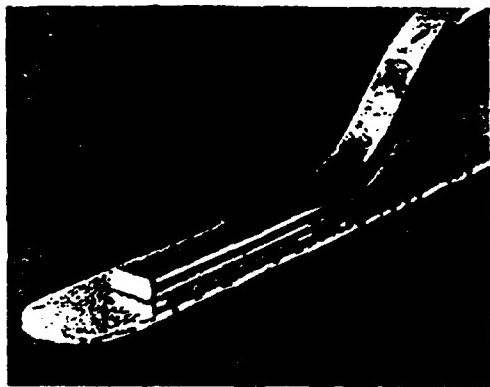
a. (MM 3-21, bot   Rank 1)

b. (mm 3-21, bot mid) Rank = 2

MAGNIFICATION 8X
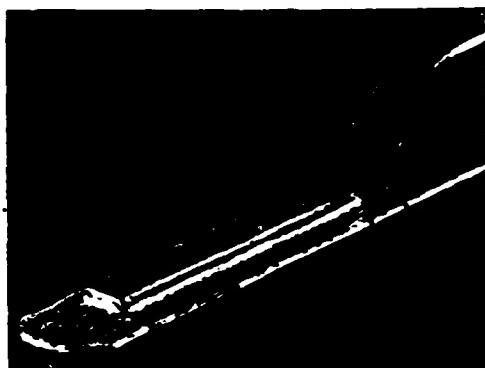
c. (mm 3-21, top) Rank = 3
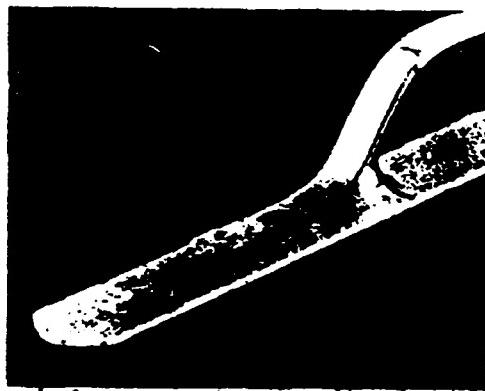
d. (mm 3-22, bot mid) Rank = 4

e. (mm 3-22, bot) Rank = 5

Table 14

Solder Ball Data

PWB SN   Diameter of largest solder ball

VI. DATA REDUCTION

1. Using the data gathered by this experiment, the response sheets typified by Table 3 will be completed for the responses; and significant interstation process variables will be identified.

2. Additional analyses of the data using analysis of variance (ANOVA) techniques will yield variability, experimental error, process capability indices, and process yield data.

Table 15
Replicate No.1 Experiment Recipe

PWB Serial Number	Random Sequence Number	Run Number	Standoff Height Prop.	Standoff Height Act.	PWB Type Prop.	PWB Type Act.	Solder Paste Vendor Prop.	Solder Paste Vendor Act.	Interaction and Error	Forced Sub-response
3001	16	1	4 mils							
3002	7	2	4 mils							
3006	15	3	4 mils							
3007	13	4	4 mils							
3011	12	5	6 mils							
3012	14	6	6 mils							
3016	6	7	6 mils							
3017	2	8	6 mils							

Proposed/Actual Variable States

Table 16
Replicate No.2 Experiment Recipe

PWB Serial Number	Random Sequence Number	Run Number	Proposed/Actual Variable States — Standoff Height (Prop.)	PWB Type (Prop.)	Solder Paste Vendor (Prop.)	Interaction and Error	Final Sub-response
3003	11	1	4 mils				
3004	9	2	4 mils				
3008	1	3	4 mils				
3009	4	4	4 mils				
3013	5	5	6 mils				
3014	10	6	6 mils				
3018	8	7	6 mils				
3019	3	8	6 mils				